

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

(NASA-CR-132663) THE 737 GRAPHITE COMPOSITE
FLIGHT SPOILER FLIGHT SERVICE EVALUATION
Annual Report, Jul. 1973 - Mar. 1975 (Boeing
Commercial Airplane Co., Seattle) 39 p HC
\$4.00

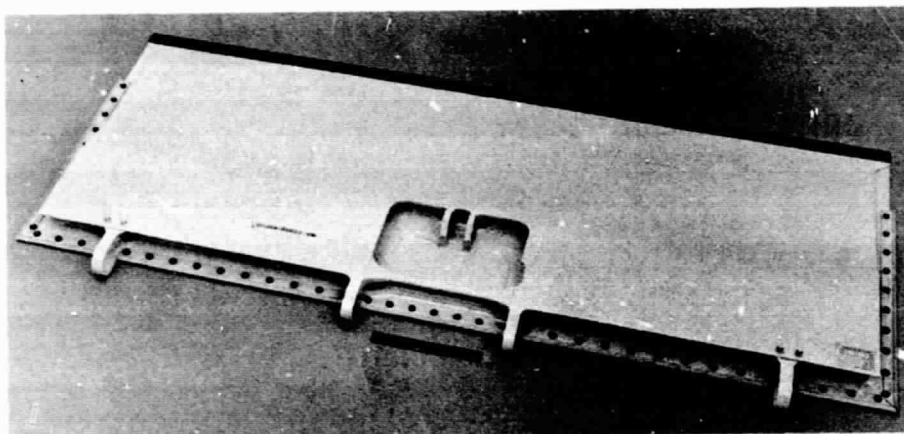
N76-32181

Unclas
05321

CSCI 01C G3/05

737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION

By Robert L. Stoecklin



FIRST ANNUAL REPORT
JULY 1973 THROUGH MARCH 1975

Prepared under contract NAS1-11668 by
BOEING COMMERCIAL AIRPLANE COMPANY
P.O. Box 3707
Seattle, Washington 98124

for
Langley Research Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

May 1975



| | | | | | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|--|
| 1. Report No. NASA CR-132663 | | 2. Government Accession No. | | 3. Recipient's Catalog No. | |
| 4. Title and Subtitle 737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION | | | | 5. Report Date May 1975 | |
| | | | | 6. Performing Organization Code | |
| 7. Author(s) Robert L. Stoecklin | | | | 8. Performing Organization Report No. | |
| 9. Performing Organization Name and Address Boeing Commercial Airplane Company P.O. Box 3707 Seattle, Washington 98124 | | | | 10. Work Unit No. | |
| | | | | 11. Contract or Grant No. NAS1-11668 | |
| 12. Sponsoring Agency Name and Address Langley Research Center National Aeronautics and Space Administration Washington, D.C. 20546 | | | | 13. Type of Report and Period Covered First Annual Report July 1973 through Mar. 1975 | |
| | | | | 14. Sponsoring Agency Code | |
| 15. Supplementary Notes NASA Technical Representative: Mr. Richard Pride | | | | | |
| 16. Abstract This flight service report was prepared in compliance with the requirements of contract NAS1-11668 and covers the flight service experience of 108 graphite-epoxy spoilers on 737 transport aircraft and related ground-based environmental exposure of graphite-epoxy material specimens for the period from July 1973 through March 1975. Four spoilers have been installed on each of 27 aircraft representing six major airlines operating throughout the world. A flight service evaluation program of at least 5 years duration is underway. As of February 28, 1975, a total of 294 280 spoiler flight-hours and 460 686 spoiler landings had been accumulated by this fleet. Based on visual, ultrasonic, and destructive testing, there has been no evidence of moisture migration into the honeycomb core and no core corrosion. Tests of removed spoilers and of ground-based exposure specimens after the first year of service indicate no significant changes in composite strength. | | | | | |
| 17. Key Words (Suggested by Author(s)) Graphite-epoxy Composite spoiler Environmental exposure | | | 18. Distribution Statement Unclassified-unlimited | | |
| 19. Security Classif. (of this report) Unclassified | | 20. Security Classif. (of this page) Unclassified | | 21. No. of Pages | |
| | | | | 22. Price* | |

*For sale by the National Technical Information Service, Springfield, Virginia 22151

ORIGINAL PAGE 1
POOR QUALITY

FOREWORD

This is the first progress report on the service evaluation of graphite-epoxy flight spoilers for 737 aircraft. This effort has been conducted as a portion of NASA contract NAS1-11668, "A Study of the Effects of Long-Term Ground and Flight Environment Exposure on the Behavior of Graphite-Epoxy Spoilers." The program is structured to gather and evaluate actual commercial service experience on a large number of graphite-epoxy specimens in a wide range of operating environments. Additional annual reports will be prepared and submitted for the duration of the flight service period, which is intended to provide at least 5 years of flight service.

This program is administered by the Langley Research Center of the National Aeronautics and Space Administration. Mr. Richard Pride of the Materials Division is the technical monitor.

The program is being conducted at the Boeing Commercial Airplane Company by Robert L. Stoecklin, technical leader, under the direction of Dr. R. R. June, program manager.

CONTENTS

| | Page |
|----------------------------------------------|------|
| PROGRAM SUMMARY AND STATUS | 1 |
| FLIGHT SERVICE EXPERIENCE | 2 |
| Geographic Installations | 2 |
| Flight Experience | 3 |
| Spoiler Removals From Service | 8 |
| STATIC TEST RESULTS | 12 |
| SERVICE PROBLEMS/REPAIRS | 15 |
| REPAIR COSTS | 26 |
| GROUND-BASED ENVIRONMENTAL SERVICE | 26 |
| REFERENCES | 36 |

PRECEDING PAGE BLANK NOT FILMED

737 GRAPHITE COMPOSITE FLIGHT SPOILER FLIGHT SERVICE EVALUATION

Robert L. Stoecklin
Boeing Commercial Airplane Company

PROGRAM SUMMARY AND STATUS

This first annual flight service report is submitted in accordance with the requirements of contract NAS1-11668 and covers the service-evaluation portion of this NASA contract for the period of July 18, 1973 through March 31, 1975. A portion of the data contained herein has previously been reported in the quarterly progress reports.

A primary objective of this program is to produce 114 graphite-epoxy 737 flight spoilers for laboratory testing and service-evaluation deployment. One spoiler of each of the three different graphite-epoxy material systems used has been laboratory tested for stiffness and strength in partial fulfillment of FAA certification requirements. Four spoilers have been installed on each of 27 aircraft representing six major airlines operating in different environmental circumstances. These units will be monitored under actual load and environmental conditions for a period of at least 5 years. Selected units will be removed periodically to evaluate any material degradation as a function of time. Six environmental exposure racks have been fabricated and positioned at major airport terminals of the participating airlines in various parts of the world to gather ground-based environmental data to support the flight data gathered from the spoilers. Significant events that have occurred during this period include:

- Deployment of all 108 graphite-epoxy spoilers
- Deployment of six environmental exposure racks with materials specimens
- Completion of the first annual inspection of the spoilers
- Selection and removal of certain spoilers from flight service for detailed inspection and static test to failure
- Retrieval and test of the first increment of ground-based exposure specimens

As of February 28, 1975, a total of 294 280 spoiler flight-hours and 460 686 spoiler landings had been accumulated by the fleet. The high time spoiler has accumulated 3525 flight-hours on New Zealand National Airways 737 ZK-NAE. Ten aircraft have accumulated in excess of 3000 flight-hours since the beginning of the flight-evaluation program.

Based on the postservice inspections, there has been no evidence of moisture migration into the honeycomb core and no core corrosion. Failure loads for spoilers in laboratory testing after 1 year of flight service were 10% to 15% less than initial tests but still exceed 200% of

design limit load. Tests of ground-based exposure specimens indicated generally less than 10% variation in material strength after 1 year of exposure when compared to results of similar baseline zero-time specimens.

Twelve spoilers were found to have sustained inservice damage. They were removed from service and have been returned to Boeing for repair. Man-hours required for repair of the first five damaged spoilers have averaged 21.2 per spoiler. After completion of repairs, the spoilers are being returned to airline service. An actuator interference problem has been identified as the principal source of inservice damage and corrective action has been taken. All participating airlines are enthusiastic about continued service evaluation.

FLIGHT SERVICE EXPERIENCE

Previous quarterly reports (ref. 1) have fully covered the fabrication, testing, certification, and deployment of the 114 spoiler units associated with task I, NASA contract NAS1-11668, with the exception of the last shipment of spoilers. The 27th and final shipset of flight spoilers was deployed by Piedmont Airlines on August 15, 1974. As a consequence, this report will deal principally with the service-evaluation effort only.

GEOGRAPHIC INSTALLATIONS

The service-evaluation program was established to place the 737 graphite-epoxy flight spoilers into a commercial service environment containing as many climatic variables as possible. No restrictions were placed on the geographical locations of candidate airlines by NASA. A survey of 737 operators disclosed that several operators were experiencing various degrees of corrosion on secondary structural honeycomb components. Since these operators functioned in a variety of climates and operated significant quantities of 737 aircraft, they were included in the list of prospective candidates. The 27 shipsets of spoilers in the program (four spoilers per shipset) were initially allocated to the following airlines in the indicated quantities.

- New Zealand National Airways—four shipsets (16 spoilers)
- Pacific Southwest Airlines—five shipsets (20 spoilers)
- Aloha Airlines—four shipsets (16 spoilers)
- Deutsche Lufthansa Airlines—six shipsets (24 spoilers)
- Piedmont Airlines—eight shipsets (32 spoilers)

This distribution was modified when PSA sold four of its participating aircraft to VASP Airlines of Sao Paulo, Brazil, in May 1974. Rather than terminate that significant portion of the program, VASP was invited to continue the spoiler evaluation on those four aircraft, which they agreed to do. VASP participation in the program is considered to be a worthwhile addition to the evaluation program. Figure 1 illustrates the geographic scope of the service-evaluation program.

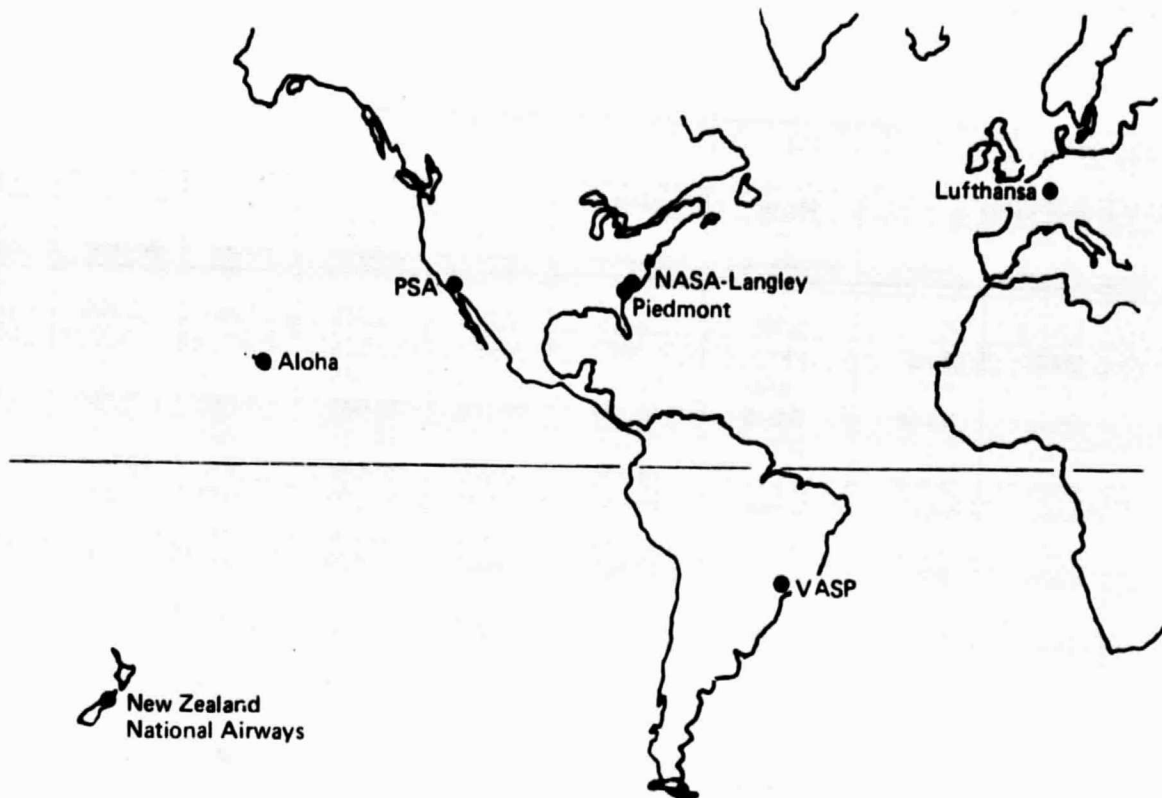


Figure 1.—Geographic Deployment of Participating Airlines

FLIGHT EXPERIENCE

The essential element in the flight service evaluation program is the commercial service exposure of the graphite-epoxy flight spoilers by scheduled carriers. The first spoiler installation was made by PSA on July 18, 1973, on 737 aircraft N987PS. The final installation was made by Piedmont Airlines on August 15, 1974, on aircraft N737N. In order to maintain a detailed accounting of the service experiences, each spoiler is maintained on a separate service record. This also permits an accounting of spoiler removals (for any reason) and reinstallation on any other aircraft and in any other mounting position on the aircraft. The total flight experience to February 28, 1975, is detailed in table 1, with the breakdown by spoiler serial number. Reinstallations are treated as a separate line item in this summary. Note that each of the graphite-epoxy material systems is designated by a separate block of serial numbers:

- Union Carbide T300/2544: 0001 to 0038
- Narmco T300/55209: 0041 to 0078
- Hercules AS/3501: 0081 to 0118

Table 2 summarizes the same data by airline. (VASP data include only flight experience since acquisition from PSA.)

Table 1.—Spoiler Service-Evaluation Program (As of February 28, 1975)

| Spoiler serial number | Airline ^a | Hours at installation | Landings at installation | Current hours | Current landings | Net hours | Net landings |
|-----------------------|----------------------|-----------------------|--------------------------|---------------|------------------|-----------|--------------|
| 0001R | PI | 5 681 | 3 056 | 7 332 | 5 476 | 1 651 | 2 420 |
| 0002 | Test | — | — | — | — | — | — |
| 0003 | PSA | 8 095 | 12 842 | 9 018 | 14 379 | 923 | 1 537 |
| 0003 | VASP | 9 018 | 14 379 | 10 970 | 16 695 | 1 952 | 2 316 |
| 0004 | PSA | 8 161 | 12 965 | 9 018 | 14 379 | 857 | 1 414 |
| 0004 | VASP | 9 018 | 14 379 | 10 970 | 16 695 | 1 952 | 2 316 |
| 0005 | PSA | 8 095 | 12 842 | 9 018 | 14 379 | 923 | 1 537 |
| 0005 | VASP | 9 018 | 14 379 | 10 970 | 16 695 | 1 952 | 2 316 |
| 0006 | PSA | 8 161 | 12 965 | 9 018 | 14 379 | 857 | 1 414 |
| 0006 | VASP | 9 018 | 14 379 | 10 970 | 16 695 | 1 952 | 2 316 |
| 0007 | NZ | 10 861 | 15 053 | 14 057 | 19 270 | 3 196 | 4 217 |
| 0008 | NZ | 10 861 | 15 053 | 14 057 | 19 270 | 3 196 | 4 217 |
| 0009 | NZ | 10 861 | 15 053 | 14 057 | 19 270 | 3 196 | 4 217 |
| 0010 | NZ | 10 861 | 15 053 | 14 057 | 19 270 | 3 196 | 4 217 |
| 0011 | LH | 11 274 | 15 681 | 14 673 | 19 935 | 3 399 | 4 254 |
| 0012 | LH | 11 274 | 15 681 | 14 673 | 19 935 | 3 399 | 4 254 |
| 0013 | LH | 11 274 | 15 681 | 14 673 | 19 935 | 3 399 | 4 254 |
| 0014 | LH | 11 274 | 15 681 | 13 329 | 18 216 | 2 055 | 2 535 |
| 0015 | PSA | 8 651 | 13 711 | 9 399 | 14 936 | 748 | 1 225 |
| 0015 | VASP | 9 399 | 14 936 | 11 257 | 17 090 | 1 858 | 2 154 |
| 0016 | PSA | 8 651 | 13 711 | 9 399 | 14 936 | 748 | 1 225 |
| 0016 | VASP | 9 399 | 14 936 | 11 257 | 17 090 | 1 858 | 2 154 |
| 0017 | PSA | 8 651 | 13 711 | 9 399 | 14 936 | 748 | 1 225 |
| 0017 | VASP | 9 399 | 14 936 | 11 257 | 17 090 | 1 858 | 2 154 |
| 0018 | PSA | 8 651 | 13 711 | 9 399 | 14 936 | 748 | 1 225 |
| 0018 | VASP | 9 399 | 14 936 | 11 257 | 17 090 | 1 858 | 2 154 |
| 0019 | LH | 11 200 | 14 884 | 14 481 | 18 981 | 3 281 | 4 097 |
| 0020 | LH | 11 200 | 14 884 | 14 481 | 18 981 | 3 281 | 4 097 |
| 0021 | LH | 11 200 | 14 884 | 14 481 | 18 981 | 3 281 | 4 097 |
| 0022 | LH | 11 200 | 14 884 | 14 481 | 18 981 | 3 281 | 4 097 |
| 0023 | Aloha | 9 207 | 24 932 | 12 087 | 32 738 | 2 880 | 7 806 |
| 0024 | Aloha | 9 207 | 24 932 | 10 974 | 29 694 | 1 767 | 4 762 |
| ^b 0024 | Aloha | 12 071 | 32 691 | 12 087 | 32 738 | 16 | 47 |
| 0025 | Aloha | 9 207 | 24 932 | 12 087 | 32 738 | 2 880 | 7 806 |
| 0026 | Aloha | 9 207 | 24 932 | 12 071 | 32 691 | 2 864 | 7 759 |
| 0027 | PI | 12 329 | 20 204 | 14 580 | 23 605 | 2 251 | 3 401 |
| 0028 | PI | 13 747 | 22 449 | 16 387 | 26 396 | 2 640 | 3 947 |
| 0029 | PI | 12 329 | 20 204 | 14 580 | 23 605 | 2 251 | 3 401 |
| 0030 | PI | 13 747 | 22 449 | 16 409 | 26 426 | 2 662 | 3 977 |
| 0031 | PI | 13 747 | 22 449 | 16 409 | 26 426 | 2 662 | 3 977 |
| 0032 | PI | 12 329 | 20 204 | 14 411 | 23 348 | 2 082 | 3 144 |
| 0033 | PI | 13 747 | 22 449 | 16 409 | 26 426 | 2 662 | 3 977 |
| 0034R | PI | 12 329 | 20 204 | 14 580 | 23 605 | 2 251 | 3 401 |
| 0035 | PI | 5 681 | 3 056 | 7 332 | 5 476 | 1 651 | 2 420 |

See footnotes at end of table.

Table 1.—(Continued)

| Spoiler serial number | Airline ^a | Hours at installation | Landings at installation | Current hours | Current landings | Net hours | Net landings |
|-----------------------|----------------------|-----------------------|--------------------------|---------------|------------------|-----------|--------------|
| 0036 | PI | 5 681 | 3 056 | 7 332 | 5 476 | 1 651 | 2 420 |
| 0037 | PI | 5 681 | 3 056 | 7 332 | 5 476 | 1 651 | 2 420 |
| 0038 | Aloha | 11 340 | 30 745 | 12 022 | 32 565 | 682 | 1 820 |
| Subtotal | | | | | | 97 106 | 146 140 |
| 0041 | Test | — | — | — | — | — | — |
| 0042 | PSA | 5 003 | 8 092 | 8 279 | 14 128 | 3 276 | 6 036 |
| 0043 | PSA | 4 993 | 8 068 | 8 279 | 14 128 | 3 285 | 6 060 |
| 0044 | PSA | 5 003 | 8 092 | 8 279 | 14 128 | 3 276 | 6 036 |
| 0045 | PSA | 4 993 | 8 068 | 6 896 | 11 280 | 1 902 | 3 212 |
| 0046 | Aloha | 6 447 | 9 087 | 9 110 | 16 040 | 2 662 | 6 953 |
| 0047 | Aloha | 6 447 | 9 087 | 9 110 | 16 040 | 2 662 | 6 953 |
| 0048 | Aloha | 6 447 | 9 087 | 9 103 | 16 022 | 2 655 | 6 935 |
| 0049 | Aloha | 6 447 | 9 087 | 9 110 | 16 040 | 2 662 | 6 953 |
| 0050 | NZ | 10 539 | 14 075 | 14 064 | 18 972 | 3 525 | 4 897 |
| 0051 | NZ | 10 539 | 14 075 | 14 064 | 18 972 | 3 525 | 4 897 |
| 0052 | NZ | 10 539 | 14 075 | 14 057 | 18 964 | 3 518 | 4 889 |
| 0053 | NZ | 10 539 | 14 075 | 13 138 | 17 747 | 2 599 | 3 672 |
| 0054 | LH | 11 152 | 15 328 | 14 437 | 19 466 | 3 285 | 4 138 |
| 0055 | LH | 11 152 | 15 328 | 14 437 | 19 466 | 3 285 | 4 138 |
| 0056 | LH | 11 152 | 15 328 | 14 437 | 19 466 | 3 285 | 4 138 |
| 0057 | LH | 11 152 | 15 328 | 14 437 | 19 466 | 3 285 | 4 138 |
| 0058 | PSA | 8 476 | 13 644 | 9 402 | 15 241 | 926 | 1 597 |
| 0058 | VASP | 9 402 | 15 241 | 11 068 | 17 343 | 1 666 | 2 102 |
| 0059 | PSA | 8 476 | 13 644 | 9 402 | 15 241 | 926 | 1 597 |
| 0059 | VASP | 9 402 | 15 241 | 11 068 | 17 343 | 1 666 | 2 102 |
| 0060 | PSA | 8 476 | 13 644 | 9 402 | 15 241 | 926 | 1 597 |
| 0060 | VASP | 9 402 | 15 241 | 11 068 | 17 343 | 1 666 | 2 102 |
| 0061 | PSA | 8 476 | 13 644 | 9 402 | 15 241 | 926 | 1 597 |
| 0061 | VASP | 9 402 | 15 241 | 11 068 | 17 343 | 1 666 | 2 102 |
| 0062 | LH | 11 450 | 15 759 | 14 501 | 19 638 | 3 051 | 3 879 |
| 0063 | LH | 11 450 | 15 759 | 14 501 | 19 638 | 3 051 | 3 879 |
| 0064 | LH | 11 450 | 15 759 | 14 501 | 19 638 | 3 051 | 3 879 |
| 0065 | LH | 11 450 | 15 759 | 14 501 | 19 638 | 3 051 | 3 879 |
| 0066 | NZ | 10 787 | 14 648 | 14 184 | 19 120 | 3 397 | 4 472 |
| 0067 | NZ | 10 787 | 14 648 | 14 191 | 19 129 | 3 404 | 4 481 |
| 0068 | NZ | 10 787 | 14 648 | 14 191 | 19 129 | 3 404 | 4 481 |
| 0069 | NZ | 10 787 | 14 648 | 14 191 | 19 129 | 3 404 | 4 481 |
| 0070 | PI | 13 908 | 22 649 | 16 534 | 26 705 | 2 626 | 4 056 |
| 0071 | PI | 13 908 | 22 649 | 16 534 | 26 705 | 2 626 | 4 056 |
| 0072 | PI | 13 908 | 22 649 | 16 534 | 26 705 | 2 626 | 4 056 |
| 0073 | PI | 15 070 | 24 630 | 16 537 | 26 785 | 1 467 | 2 155 |
| 0074 | PI | 13 908 | 22 649 | 16 534 | 26 705 | 2 626 | 4 056 |

See footnotes at end of table.

Table 1.— (Continued)

| Spoiler serial number | Airline ^a | Hours at installation | Landings at installation | Current hours | Current landings | Net hours | Net landings |
|-----------------------|----------------------|-----------------------|--------------------------|---------------|------------------|-----------|--------------|
| 0075 | PI | 15 070 | 24 630 | 16 537 | 26 785 | 1 467 | 2 155 |
| 0076 | PI | 15 070 | 24 630 | 16 537 | 26 785 | 1 467 | 2 155 |
| 0077 | PI | 15 070 | 24 630 | 16 537 | 26 785 | 1 467 | 2 155 |
| 0078 | Aloha | 9 343 | 25 410 | 11 340 | 30 728 | 1 997 | 5 318 |
| ^b 0078 | Aloha | 9 103 | 16 022 | 9 110 | 16 040 | 7 | 18 |
| Subtotal | | | | | | 103 244 | 162 452 |
| 0081 | Test | — | — | — | — | — | — |
| 0082 | LH | 11 560 | 16 962 | 14 760 | 21 009 | 3 200 | 4 047 |
| 0083 | LH | 11 560 | 16 962 | 14 760 | 21 009 | 3 200 | 4 047 |
| 0084 | LH | 11 560 | 16 962 | 14 760 | 21 009 | 3 200 | 4 047 |
| 0085 | LH | 11 560 | 16 962 | 14 760 | 21 009 | 3 200 | 4 047 |
| 0086 | NZ | 5 587 | 8 565 | 8 869 | 12 945 | 3 282 | 4 380 |
| 0087 | NZ | 5 587 | 8 565 | 8 869 | 12 945 | 3 282 | 4 380 |
| 0088 | NZ | 5 587 | 8 565 | 8 869 | 12 945 | 3 282 | 4 380 |
| 0089 | NZ | 5 587 | 8 565 | 7 272 | 10 794 | 1 685 | 2 229 |
| ^b 0089 | NZ | 8 771 | 12 820 | 8 869 | 12 945 | 98 | 125 |
| 0090 | Aloha | 5 623 | 7 992 | 6 788 | 10 937 | 1 165 | 2 945 |
| ^b 0090 | Aloha | 11 344 | 30 728 | 12 022 | 32 565 | 678 | 1 837 |
| 0091 | Aloha | 5 623 | 7 992 | 8 035 | 14 174 | 2 412 | 6 182 |
| 0092 | Aloha | 5 623 | 7 992 | 8 035 | 14 174 | 2 412 | 6 182 |
| 0093 | PI | 13 879 | 22 839 | 16 272 | 26 469 | 2 393 | 3 630 |
| 0094 | PI | 13 879 | 22 839 | 16 272 | 26 469 | 2 393 | 3 630 |
| 0095 | PI | 13 879 | 22 839 | 16 272 | 26 469 | 2 393 | 3 630 |
| 0096 | PI | 13 879 | 22 839 | 16 272 | 26 469 | 2 393 | 3 630 |
| 0097 | — | — | — | — | — | — | — |
| 0098 | Aloha | 9 244 | 25 150 | 12 022 | 32 565 | 2 778 | 7 415 |
| 0099 | PI | 10 290 | 15 517 | 12 847 | 19 387 | 2 557 | 3 870 |
| 0100 | PI | 12 641 | 20 584 | 14 929 | 24 093 | 2 288 | 3 509 |
| 0101 | PI | 10 290 | 15 517 | 12 847 | 19 387 | 2 557 | 3 870 |
| 0102 | PI | 10 290 | 15 517 | 12 847 | 19 387 | 2 557 | 3 870 |
| 0103 | PI | 12 641 | 20 584 | 14 929 | 24 093 | 2 288 | 3 509 |
| 0104 | Aloha | 9 244 | 25 150 | 11 340 | 30 745 | 2 096 | 5 595 |
| 0105 | Aloha | 9 244 | 25 150 | 9 343 | 25 410 | 99 | 260 |
| ^b 0105 | Aloha | 6 916 | 11 247 | 8 035 | 14 174 | 1 110 | 2 927 |
| 0106 | Aloha | 5 623 | 7 992 | 8 035 | 14 174 | 2 412 | 6 182 |
| 0107 | Aloha | 9 244 | 25 150 | 12 022 | 32 565 | 2 778 | 7 415 |
| 0108 | PSA | 8 621 | 13 711 | 9 568 | 15 160 | 947 | 1 449 |
| 0108 | VASP | 9 568 | 15 160 | 11 322 | 17 314 | 1 754 | 2 154 |
| 0109 | PSA | 8 621 | 13 711 | 9 568 | 15 160 | 947 | 1 449 |
| 0109 | VASP | 9 568 | 15 160 | 11 322 | 17 314 | 1 754 | 2 154 |
| 0110 | PSA | 8 621 | 13 711 | 9 568 | 15 160 | 947 | 1 449 |
| 0110 | VASP | 9 568 | 15 160 | 11 322 | 17 314 | 1 754 | 2 154 |

See footnotes at end of table.

Table 1.—(Concluded)

| Spoiler serial number | Airline ^a | Hours at installation | Landings at installation | Current hours | Current landings | Net hours | Net landings |
|-----------------------|----------------------|-----------------------|--------------------------|---------------|------------------|-----------|--------------|
| 0111 | PSA | 8 621 | 13 711 | 9 568 | 15 160 | 947 | 1 449 |
| 0111 | VASP | 9 568 | 15 160 | 11 322 | 17 314 | 1 754 | 2 154 |
| 0112 | LH | 11 587 | 16 011 | 14 536 | 19 767 | 2 949 | 3 756 |
| 0113 | LH | 11 587 | 16 011 | 14 536 | 19 767 | 2 949 | 3 756 |
| 0114 | LH | 11 587 | 16 011 | 14 536 | 19 767 | 2 949 | 3 756 |
| 0115 | LH | 11 587 | 16 011 | 14 536 | 19 767 | 2 949 | 3 756 |
| 0116 | PI | 10 290 | 15 517 | 12 847 | 19 387 | 2 557 | 3 870 |
| 0117 | PI | 12 641 | 20 584 | 14 929 | 24 093 | 2 288 | 3 509 |
| 0118 | PI | 12 641 | 20 584 | 14 929 | 24 093 | 2 288 | 3 509 |
| Subtotal | | | | | | 93 930 | 152 094 |
| Grand total | | | | | | 294 280 | 460 686 |

^aPI is Piedmont Airlines.

VASP is Viacao Aerea Sao Paulo Airlines, Brazil.

NZ is New Zealand National Airways.

LH is Lufthansa German Airlines.

^bReinstallation

Table 2.—Flight Spoiler Service Experience (Through February 28, 1975)

| Airline | Number of aircraft in evaluation | Number of spoilers in evaluation | Total spoiler hours since installation | Total spoiler landings since installation |
|-------------|----------------------------------|----------------------------------|----------------------------------------|-------------------------------------------|
| PSA | 1 | 4 | 25 783 | 44 330 |
| Aloha | 4 | 16 | 41 683 | 110 070 |
| New Zealand | 4 | 16 | 51 189 | 68 632 |
| Lufthansa | 6 | 24 | 75 316 | 94 965 |
| Piedmont | 8 | 32 | 71 389 | 107 785 |
| VASP | 4 | 16 | 28 920 | 34 904 |
| Total | 27 | ^a 108 | 294 280 | 460 686 |

^aCurrent total now 105 spoilers, with 3 spoilers removed for static testing.

Figure 2 is a plot of the history of flight-hours and landings, with the experience curves projected into late 1975.

Figures 3 and 4, photos taken at the Winston-Salem, N.C., and Frankfurt/Main airports, respectively, show representative equipment involved in the program and lend substance to the geographical scope of the program.

SPOILER REMOVALS FROM SERVICE

Several spoiler units were removed from service and reinstalled at a later date. Table 3 summarizes these removals and notes the reasons and disposition in each case.

The most significant problem area has been the occurrence of upper surface skin blisters. This problem has been investigated and determined to be the result of an interference between the actuator rod end and the inner surface of the upper skin, when the rod end is in the "hard-over" position. Since the graphite skin is thicker, ≈ 0.091 vs 0.081 cm (≈ 0.036 vs 0.032 in.), and stiffer than its counterpart on the production aluminum spoiler, the graphite skin cannot accept the forced deflection without suffering an interlaminar shear failure. This type of problem was first noted in October 1973 on an Aloha 737. After the third such incident was reported in July 1974, a fleet survey of Aloha was conducted by the program technical leader. This survey disclosed six additional spoiler blisters not previously reported. Discovery of the rod-end interference problem led to a program-wide survey of all participating airlines to assess the extent of blister damage. This survey (October through November) disclosed three additional blistered spoilers on aircraft of two of the other airlines.

The immediate corrective action available was to replace the offending rod ends with the optional rod end which offers a spherical housing configuration (fig. 5). Replacement rod ends were furnished to Aloha, and rod ends for the remaining airlines were distributed during the January 1975 inspection tour.

During the January 1975 inspection tour, seven previously unreported blistered spoilers were identified, making a total of 19 spoilers so damaged. In order to preclude compromising the evaluation program, arrangements have been made with the airlines involved to return the blistered spoilers to Boeing for repair, after which the spoilers will be returned to the respective airlines for reinstallation. These reinstallations account for the multiple entries for certain spoilers in the flight service summary. (Refer to table 1.)

In June 1974, New Zealand National Airways reported that spoiler S/N 0089 had been inadvertently damaged by a control cable during aircraft overhaul. The nature of the damage was a slot cut through the spoiler thickness for a length of approximately 6.6 cm (2.6 in.) from the trailing edge. This damage has been repaired by Boeing, and the spoiler has been returned to National Airways and reinstalled.

Since the blister problem is totally unrelated to the service performance of the graphite-epoxy spoiler and the only other removal incident (S/N 0089) was attributable to maintenance damage, the appraisal of spoiler performance at 19 months after initial introduction into service can best be assessed as "no problems." The unyielding nature of

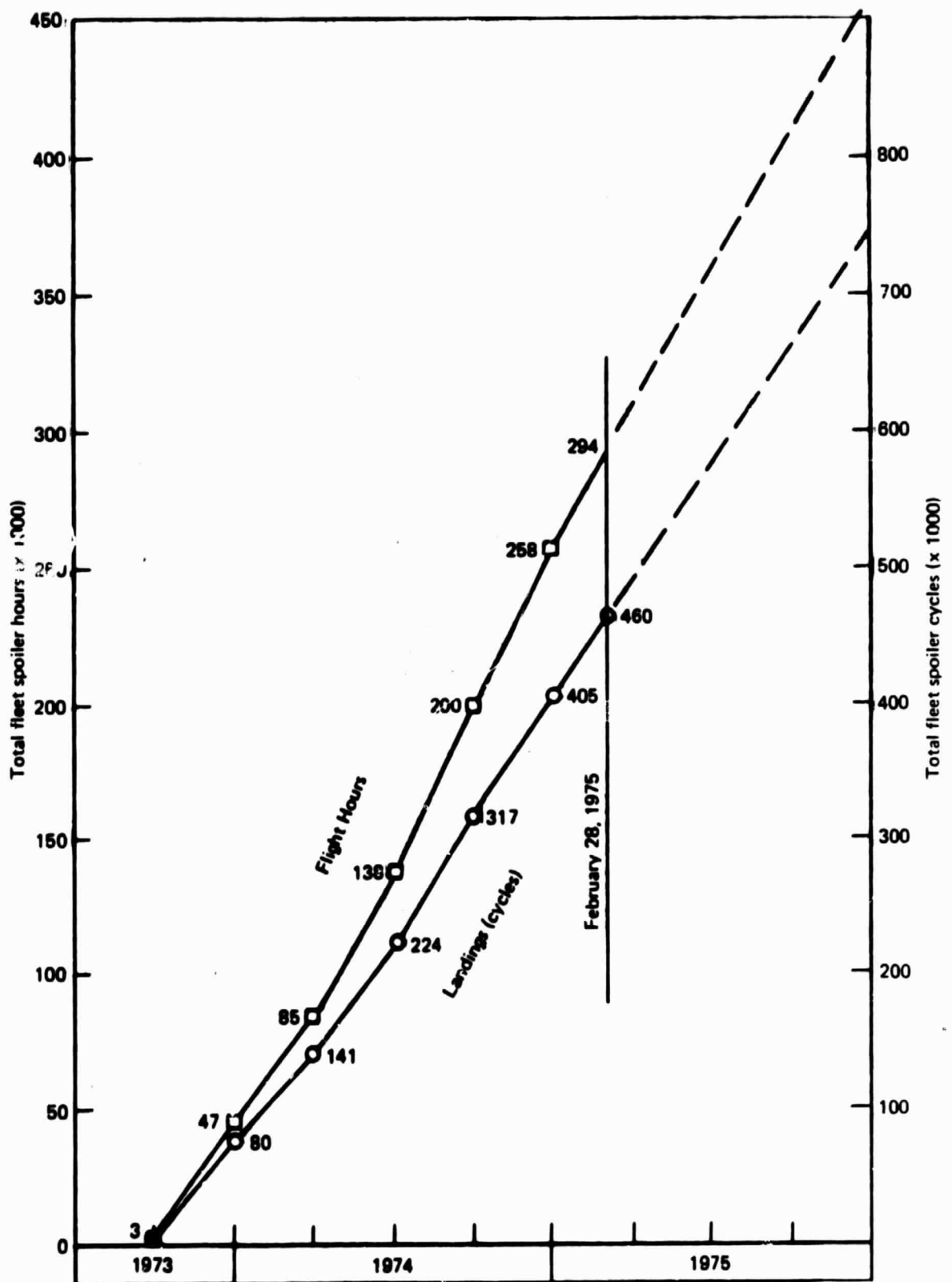


Figure 2.—Cumulative Fleet Flight-Hours and Landings



Figure 3.—Participating 737 at Winston-Salem Airport



Figure 4.—Participating 737 at Frankfurt/Main Airport

Table 3.—Flight Spoiler Removal Summary (As of February 28, 1975)

| Spoiler serial number | Airline | Date removed | Reason for removal | Action taken | Final disposition |
|-----------------------|-------------|--------------|----------------------------------------|---------------------------|-------------------|
| 0014 | Lufthansa | 7-29-74 | 1-yr evaluation | NDT and skin repair | Static test |
| 0024 | Aloha | 7-11-74 | Upper skin blister | NDT and skin repair | Reinstalled |
| 0026 | Aloha | 2-25-75 | Upper skin blister | NDT and skin repair | To be reinstalled |
| 0028 | Piedmont | 2-24-75 | 1-yr evaluation | NDT | To spares |
| 0032 | Piedmont | 1-28-75 | Upper skin blister | NDT and skin repair | To be reinstalled |
| 0045 | PSA | 7-14-74 | 1-yr evaluation | NDT | To spares |
| 0048 | Aloha | 2-25-75 | Upper skin blister | NDT and skin repair | To be reinstalled |
| 0052 | New Zealand | 2-27-75 | Upper skin blister | NDT | To be reinstalled |
| 0053 | New Zealand | 9-24-74 | 1-yr evaluation | NDT | Static test |
| 0059 | VASP | 1-10-75 | Upper skin blister | NDT and skin repair | To be reinstalled |
| 0067 | New Zealand | 2-27-75 | Upper skin blister | NDT | To be reinstalled |
| 0078 | Aloha | 10-24-74 | Upper skin blister | NDT and skin repair | Reinstalled |
| 0089 | New Zealand | 6-21-74 | Maintenance damage to TE | NDT, skin and core repair | Reinstalled |
| 0090 | Aloha | 5-2-74 | Upper skin blister | NDT and skin repair | Reinstalled |
| 0104 | Aloha | 10-25-74 | Upper skin blister and 1-yr evaluation | NDT | Static test |
| 0105 | Aloha | 10-17-73 | Upper skin blister | NDT and skin repair | Reinstalled |

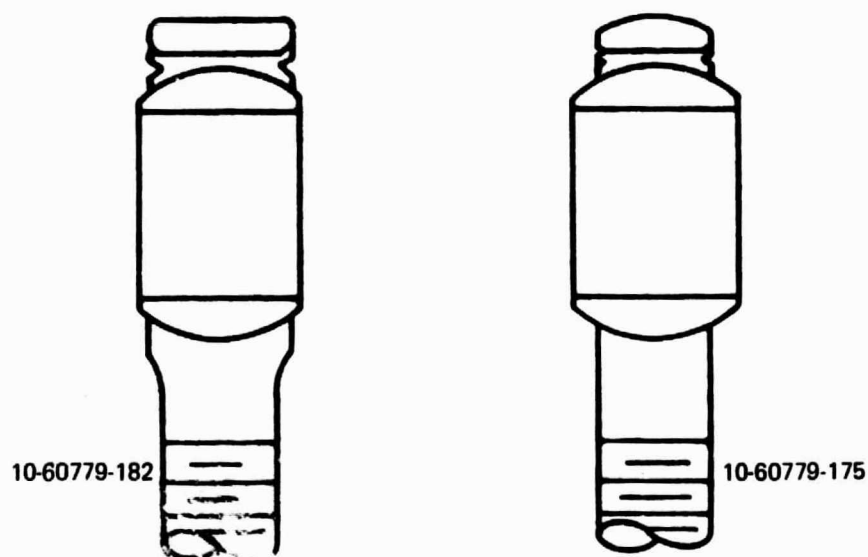


Figure 5.—Actuator Rod End Cross Sections

the laminates points out very clearly that extreme caution must be exercised to avoid undesired forced displacements of the laminates. No evidence of corrosion or deterioration of the skin laminates has been observed. One case of corrosion of the aluminum bearing doublers on the spoiler lower skin was observed (spoiler S/N 0048, fig. 6). Investigation of this condition is continuing.

Five spoilers were selected at random for removal following the first year of service. Visual inspection of these units showed no detectable defects and only the oil and dirt associated with trailing edge components, except for spoilers S/N 0014 and 0104. Spoiler S/N 0014 showed evidence of delamination of a repair on the upper surface skin above the center hinge fitting (fig. 7). Spoiler S/N 0104 showed an upper surface skin blister, approximately 3 cm (1.2 in.) in diameter, above the center hinge fitting (CHF), which was not repaired prior to its destruction in static test.

All five spoilers were reexamined by ultrasonic testing techniques in the same manner as was employed in the original fabrication process. Comparisons between the two sets of ultrasonic recordings showed no detectable internal defects or disbonds and confirmed the external defects on S/N 0014 and 0104 which were visually noted.

The spoilers that were subjected to static test following 1 year of service evaluation (S/N 0014, 0053, and 0104) were subsequently sawed open and examined for evidence of corrosion. Careful inspection of the inside surface of each skin laminate showed no evidence of corrosion.

In addition, no evidence of deterioration was found attributable to the presence of grease, oil, dirt, or Skydrol.

STATIC TEST RESULTS

As a portion of the service-evaluation program, additional static testing of spoilers removed from flight service was conducted. The plan was to test one randomly selected spoiler of each graphite-epoxy material system to destruction. After 1 year of service, comparison of test data with the test data obtained on similar spoilers having no service exposure experience would be made to ensure a continued level of safety margin.

The spoilers selected for static test are listed in table 4.

Table 4.—Static Test Spoilers

| Graphite-epoxy material system | Spoiler serial number | Operator airline | Total flight-hours in service | Total time in service |
|--------------------------------|-----------------------|------------------|-------------------------------|-----------------------|
| T300/2544 | 0014 | Lufthansa | 2055 | 11 mo, 3 days |
| T300/5209 | 0053 | New Zealand | 2599 | 14 mo, 1 day |
| AS/3501 | 0104 | Aloha | 2096 | 13 mo, 0 days |

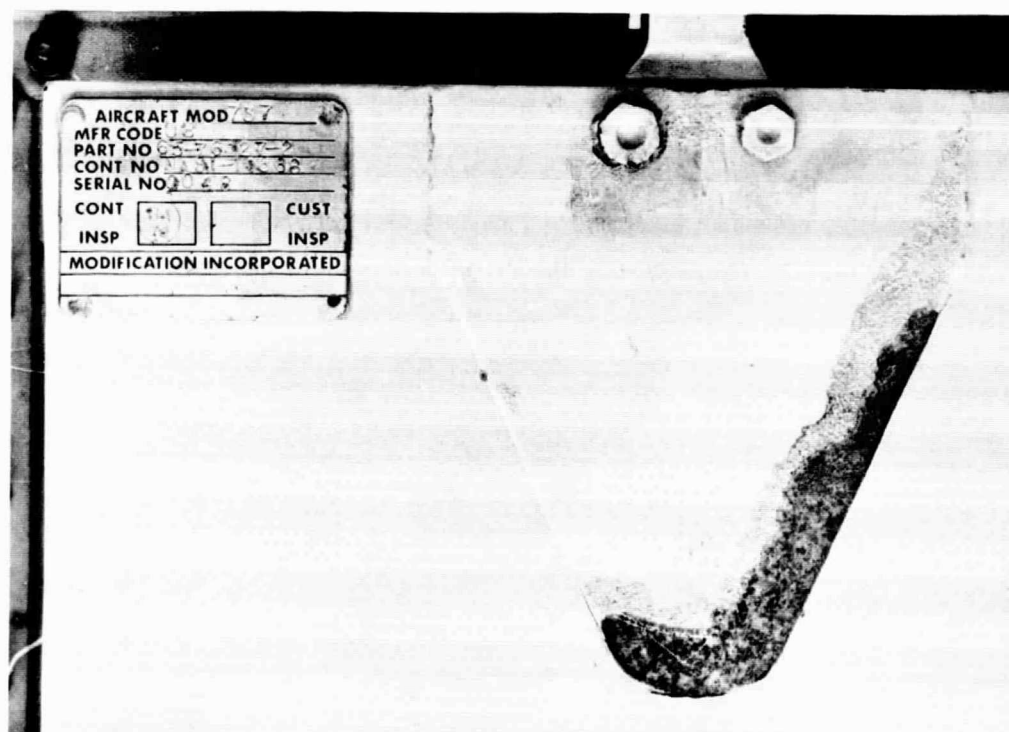
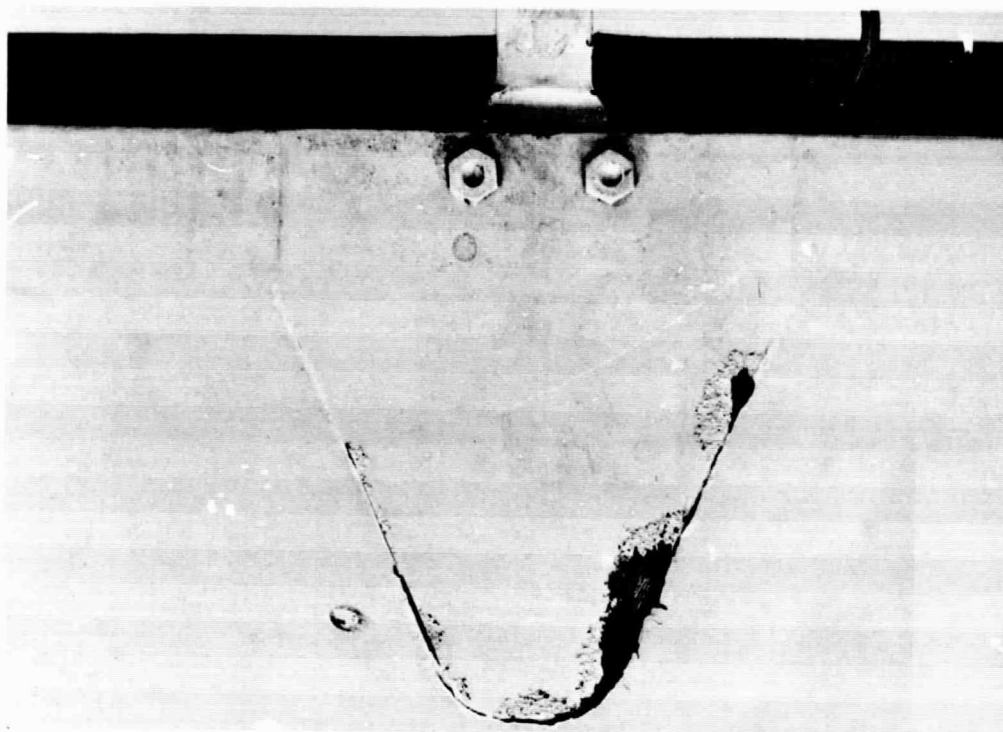


Figure 6.—Corrosion on -23 Doubler

ORIGINAL PAGE IS
OF POOR QUALITY

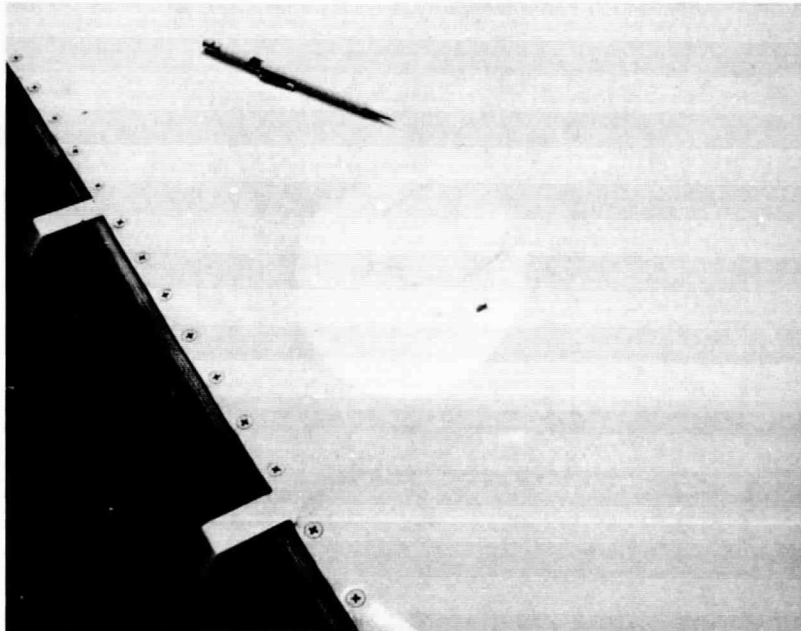


Figure 7.—Upper Surface Repair Delamination on S/N 0014

The static test setup from the original certification testing was used to conduct these tests. All three tests were conducted on the same working day. Test results are plotted in figures 8, 9, and 10, with the corresponding plots of the certification testing included in each figure. Failure load levels of the current tests are considered satisfactory since they equal or exceed the values achieved by the production aluminum spoiler (ref. 1, Third Quarterly Report, April 1973). Photos of the failed test spoilers are shown in figures 11, 12, and 13.

In comparing the test results of the current test series with the original certification testing, the following differences were noted:

1. Initial failure of S/N 0014 was brought about by the combination of shearing of the -11 aluminum doubler above the CHF and failure of the repair patch on the upper skin above the CHF. The failure load achieved was attained despite a "resin only" joint around the edges of the repair. Repair procedures have been modified to include EA 9628 adhesive in the repair lap joints. Although the failure occurred in the skin repair area, the percentage loss in failure load was essentially no greater than for the other two test specimens. Failure of the comparable certification test spoiler (S/N 0002) was attributable to lower surface skin buckling near the CHF due to deflection of the CHF.
2. Failure mode of the T300/5209 spoiler (S/N 0053) has been assessed as a primary lower skin buckling immediately adjacent to the CHF. An additional failure of the -11 aluminum doubler under the upper skin precipitated the upper skin tension failure. Both failures were influenced by deflection of the CHF. Failure of the comparable certification test spoiler (S/N 0041) was attributed to upper surface skin tension failure precipitated by yielding and failure of the CHF.
3. Failure mode of the AS/3501 spoiler (S/N 0104) was indicative of a shear failure in the bondline between the honeycomb core and the CHF, with secondary shear failure in the honeycomb core along the spoiler centerline. The comparable certification test spoiler (S/N 0081) failed in buckling of the lower skin near the CHF, with a resulting honeycomb core shear failure along the spoiler centerline.

SERVICE PROBLEMS/REPAIRS

During the course of the 19-1/2 months that the service-evaluation program has been in progress, a number of flight spoilers have been returned to Boeing. These returns were occasioned by one of the following reasons:

- Scheduled 1-year removal (4 units)
- Upper surface skin blister (11 units)
- Maintenance damage (1 unit)

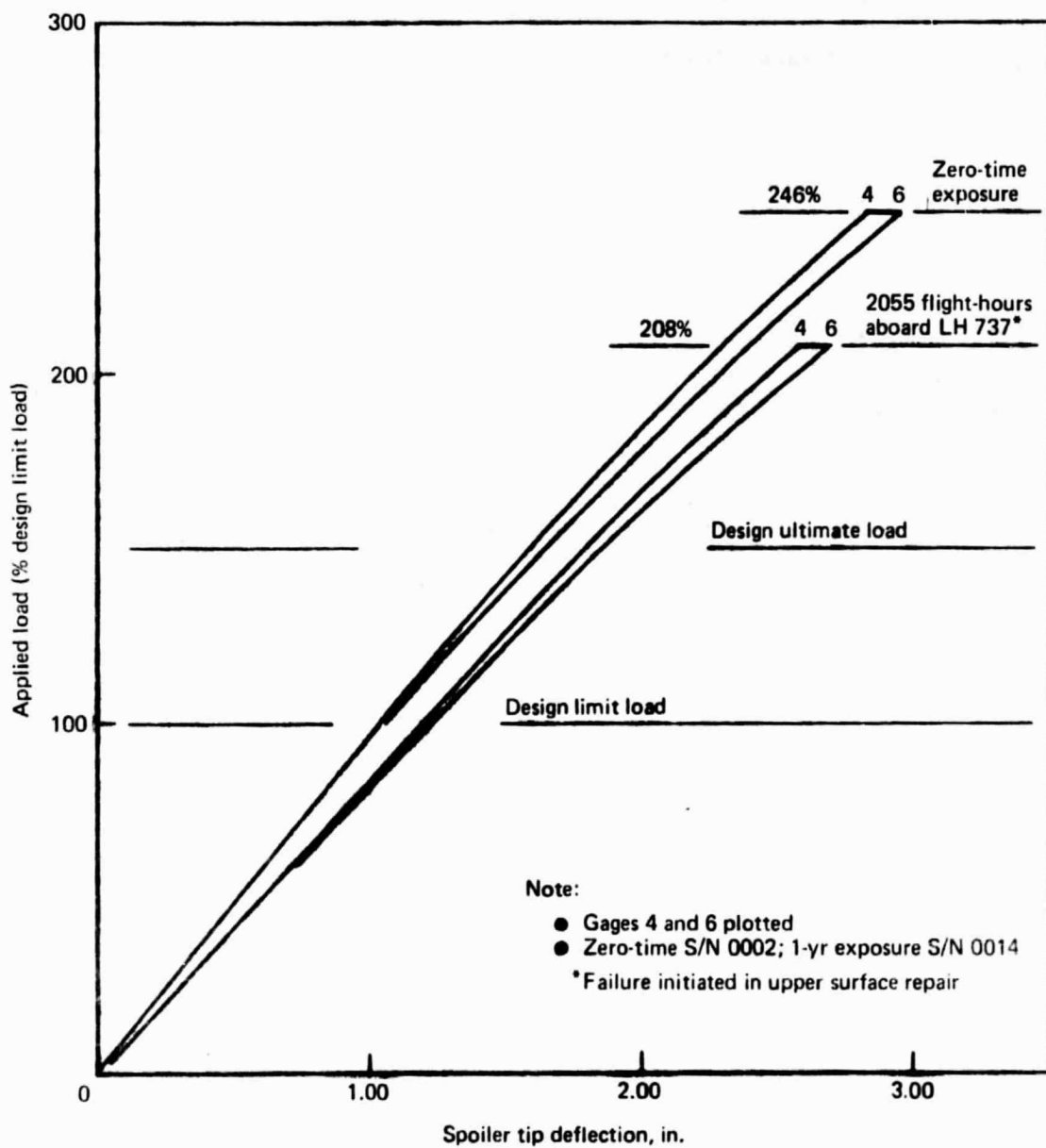


Figure 8.—Load-Deflection Curves—Zero-Time and 1-Year Exposure
(Union Carbide T300/2544 Material System)

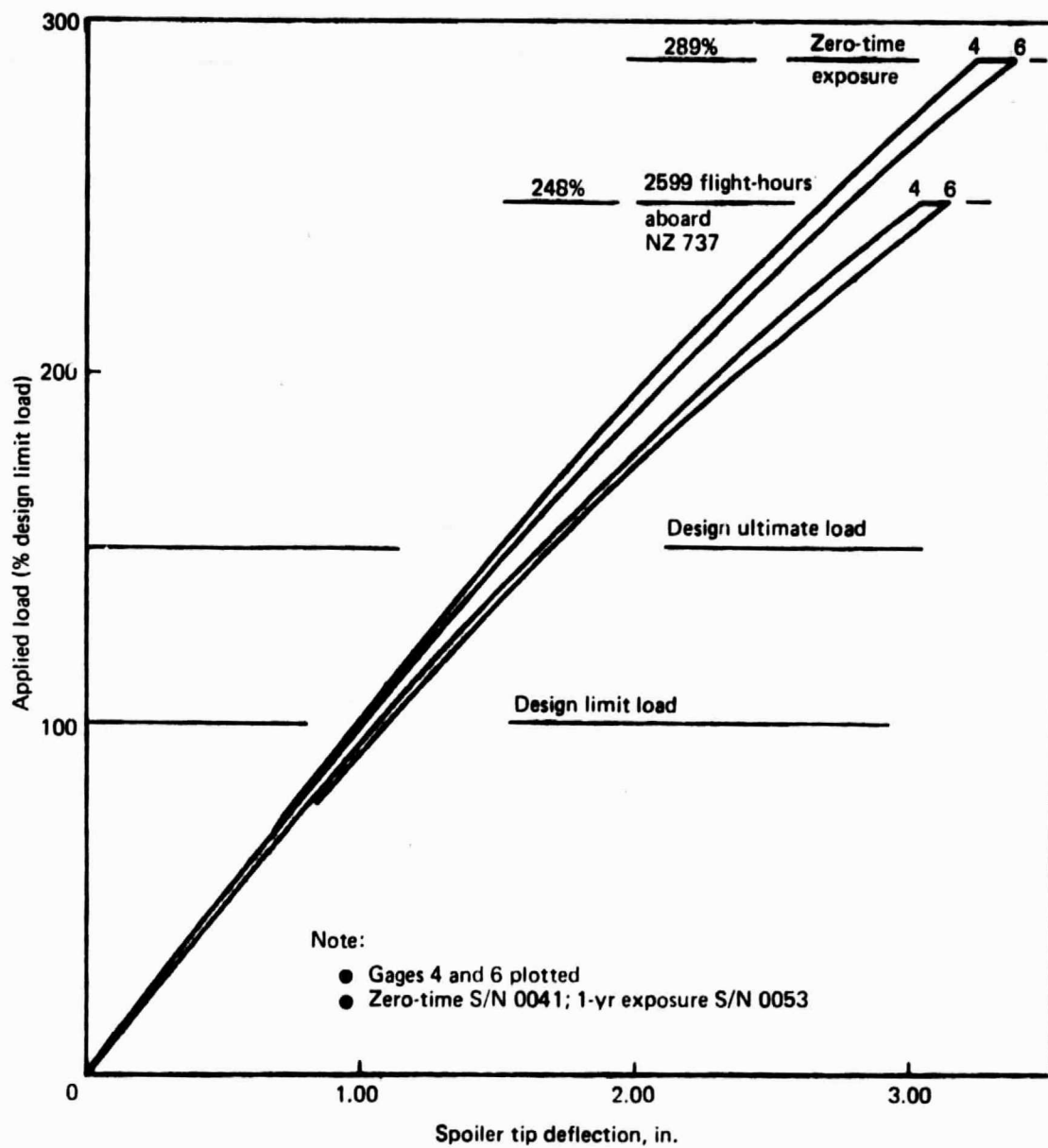


Figure 9.—Load-Deflection Curves—Zero-Time and 1-Year Exposure
(Narmco T300/5209 Material System)

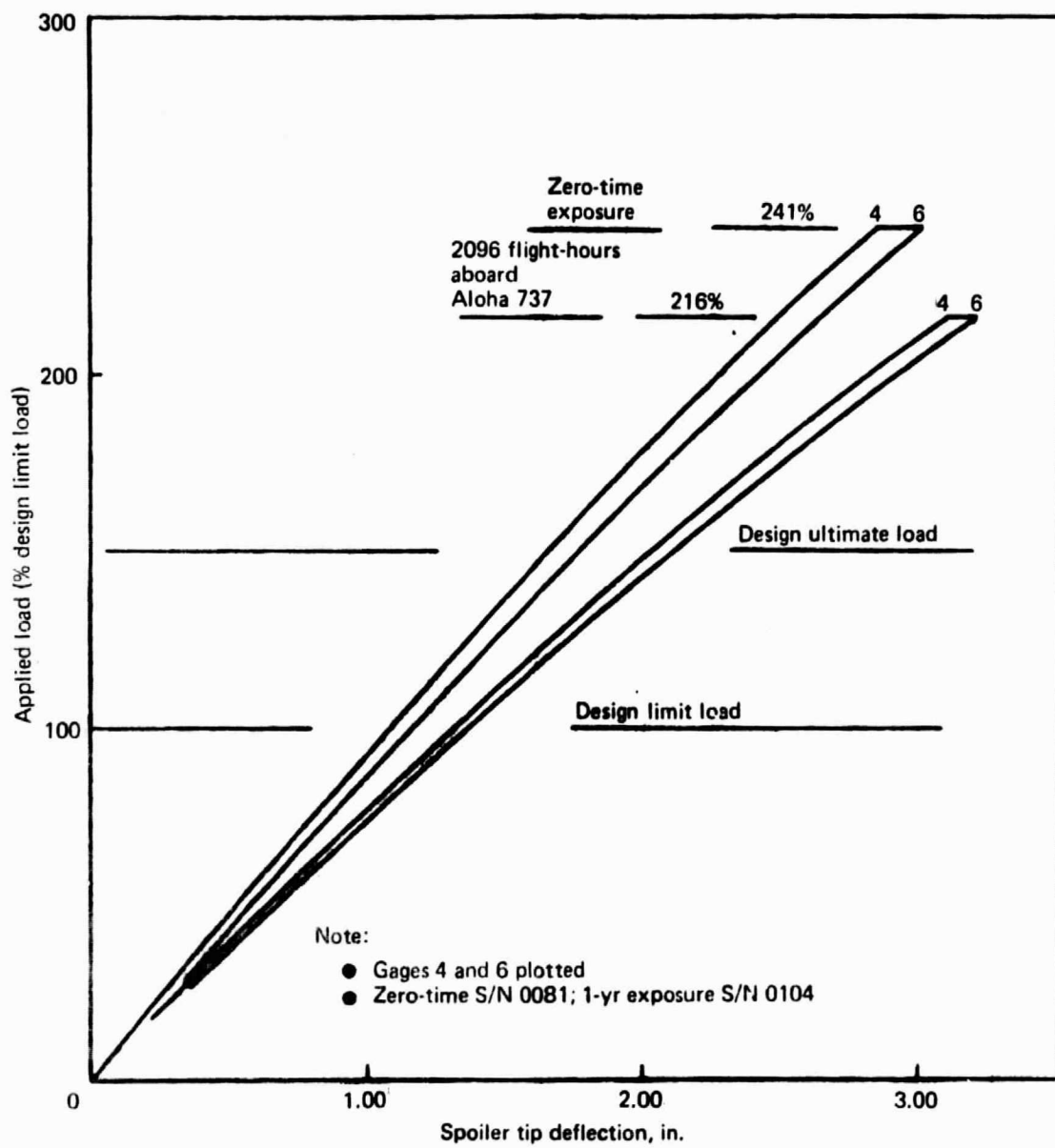


Figure 10.—Load-Deflection Curves—Zero-Time and 1-Year Exposure
(Hercules AS/3501 Material System)

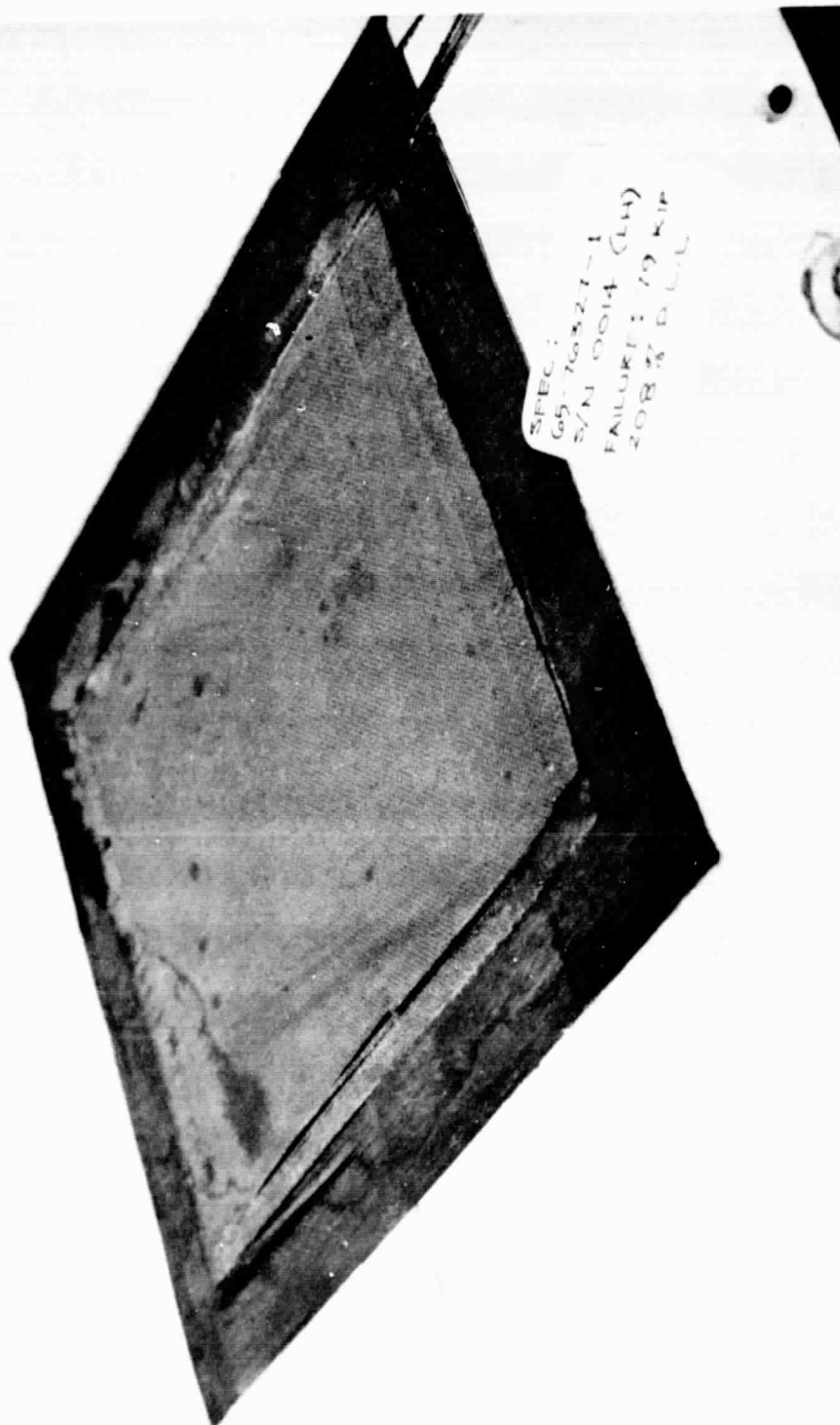


Figure 11.—Failure of S/N 0014 Through Repair

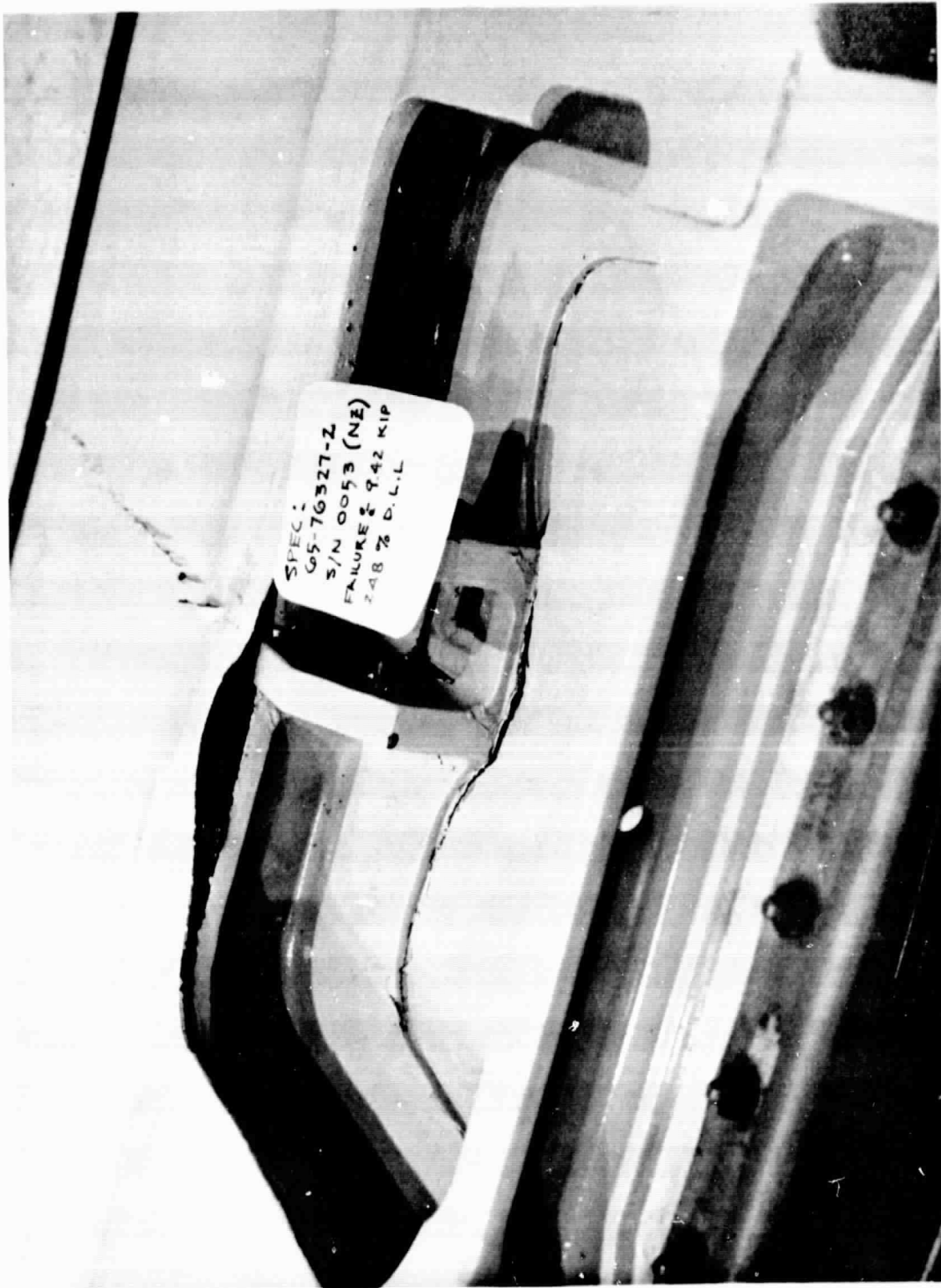


Figure 12. —Failure of S/N 0053 Above and Below Center Hinge Fitting



Figure 13. - Failure of S/N 0104 Adjacent to Center Hinge Fitting

A discussion of the background of the upper surface skin blister problem was made in the "Removals From Service" section of this report. This problem alone accounted for 90% of the total number of unplanned removals. It is interesting to note that 7 of the 11 blister removals to date have come from Aloha 737's. Aloha also accounted for the highest number of cycles (landings) of graphite-epoxy flight spoilers in the service evaluation.

Agreement was reached with the participating airlines to return all blistered spoilers to Boeing for repair. The procedure for repair was as follows, after receipt of a spoiler at Boeing:

- Quality Control initiated rejection tag.
- Quality Control performed complete color C-scan.
- MRB engineer wrote repair disposition.
- Shop removed defect from skin and prepared laminate for repair layup. For blister repair, each ply of skin was stepped back approximately 0.6 cm (0.25 in.) from the preceding ply, and the repair ply was overlaid to provide an adequate shear tie. Film adhesive was added in the ply overlap.
- Shop laid up prepreg repair and completely bagged spoiler in bond assembly tool.
- Spoiler was autoclave-cured and debagged.
- Quality Control performed color C-scan.
- MRB engineer accepted repair.
- Spoiler surface was refinished; seals and bearings were reinstalled; spoiler was prepared for shipment.

In one instance (S/N 0024), the spoiler, with the upper skin repaired, was not placed in the bonding assembly tool. Instead, a partial bag was prepared covering the repair only. Following autoclave cure and bag removal, a large oval-shaped void, approximately 20 x 30 cm (7.8 x 11.7 in.), was visually noted in the central portion of the lower skin.

The color scan which followed the repair confirmed the void. To visually assess the problem, an oval section of skin was removed (fig. 14). Further examination disclosed that those areas adjacent (in the spanwise direction) to the initial void were also voided or weakly attached. Progressive removal of the entire lower skin was successfully accomplished (fig. 15). An entire new lower skin was successfully bonded to the spoiler frame, with the subsequent NDT inspection showing a void-free bondline. Following the repainting and reinstallation of details, the spoiler was returned to service.

Photos of the New Zealand spoiler (S/N 0089) show the damaged trailing edge before repair (fig. 16) and after repair (fig. 17).

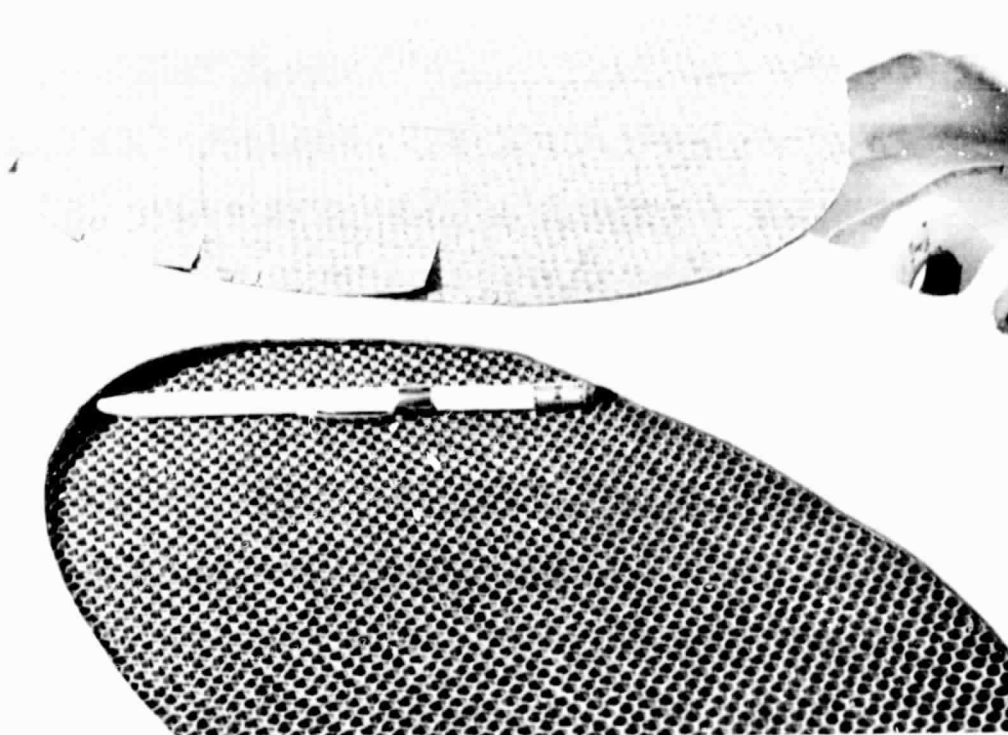


Figure 14.—Skin Removed From S/N 0024

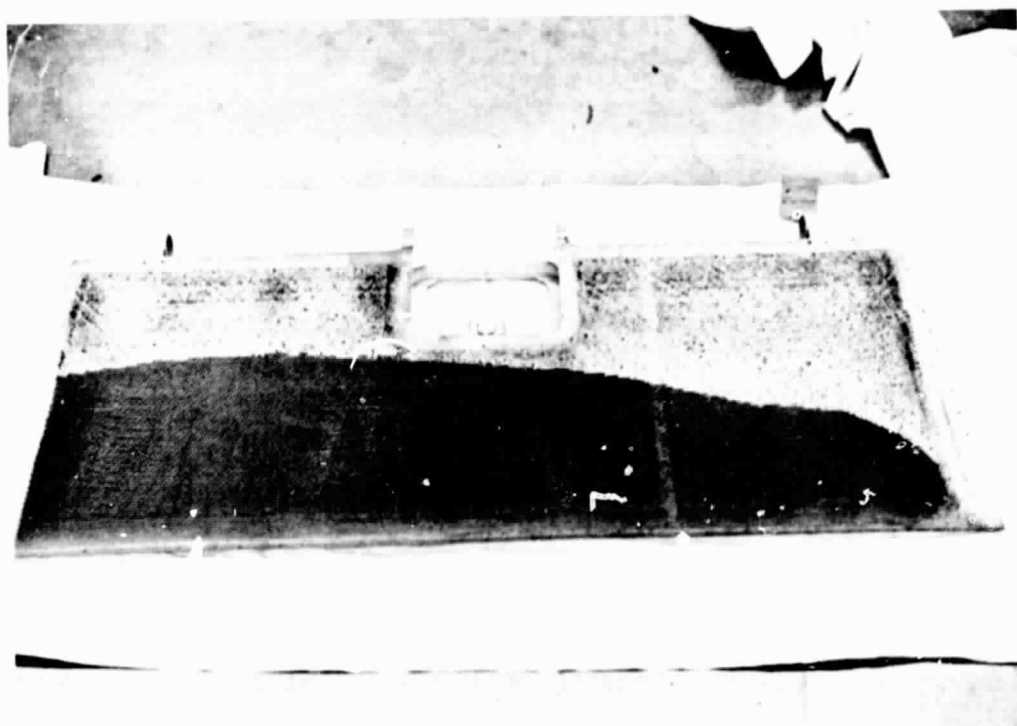


Figure 15.—Lower Skin Completely Removed From S/N 0024

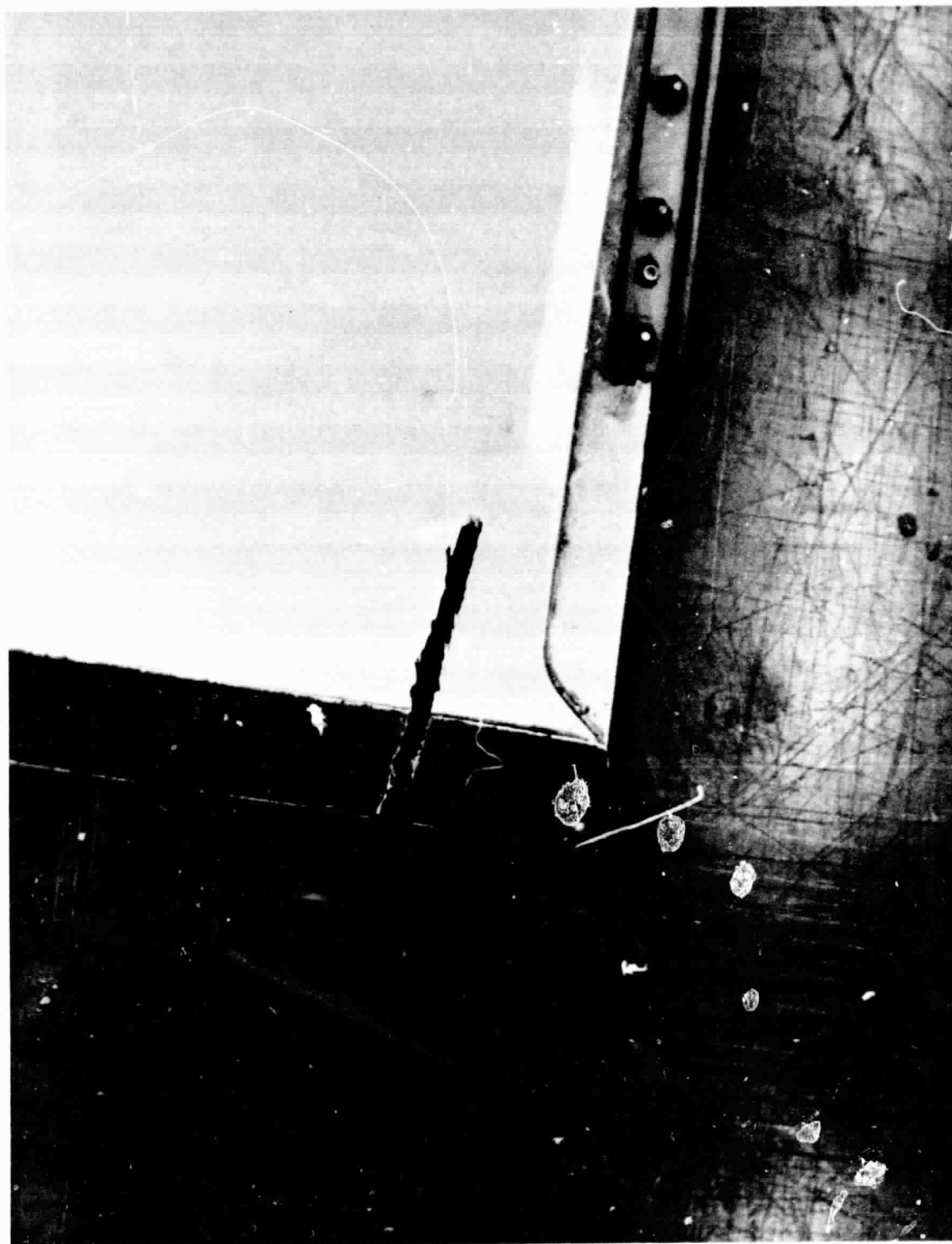


Figure 16.—Damaged Trailing Edge of S/N 0089

ORIGINAL PAGE IS
OF POOR QUALITY



Figure 17.—Repaired Trailing Edge of S/N 0089

REPAIR COSTS

Several repair requirements for spoiler skin laminates were generated as a result of circumstances discussed in the "Removals From Service" section of this report. Upon recognition of the repair need, those spoiler units so identified were returned to Boeing for repair.

A direct charge system was employed in the Auburn fabrication facility to track man-hour costs associated with each repair. Each unit was identified in the accounting system using the rejection tag serial number to identify charges for each unit. Table 5 gives the breakdown of the repair hours accumulated on five completed repairs. Refinishing man-hours have been prorated when more than one unit was processed at one time. No material costs have been included in this accounting as they were considered to be insignificant. Charges for the repair of S/N 0024 reflect the additional effort of replacing the lower skin.

Table 5.—Repair Cost Data (Man-Hour Charges)

| Spoiler serial number | Airline | Final assembly | Detail assembly | Production control | Painting and finishing | Total |
|-----------------------|-------------|----------------|-----------------|--------------------|------------------------|-------|
| 0024 | Aloha | 3.3 | 18.5 | 0.3 | 7.7 | 29.8 |
| 0089 | New Zealand | 4.1 | 6.0 | 0.3 | 7.7 | 18.1 |
| 0090 | Aloha | 4.1 | 8.5 | 0.2 | 7.7 | 20.5 |
| 0014 | Lufthansa | 5.3 | 10.8 | 0.2 | 0 | 16.3 |
| 0078 | Aloha | 2.8 | 8.5 | 0.2 | 9.6 | 21.1 |
| Total | | 19.6 | 52.3 | 1.2 | 32.7 | 105.8 |
| Average | | 3.92 | 10.46 | 0.24 | 6.54 | 21.16 |

Each spoiler repair required hand preparation of the laminate to remove the defect, hand layup, and autoclave cure of the graphite-epoxy repair patch. Engineering direction for each repair was individually prepared. Each unit was nondestructively inspected both prior to and following each repair.

GROUND-BASED ENVIRONMENTAL SERVICE

Concurrent with the flight service evaluation program of the flight spoilers, specimens of the same composite material systems are being subjected to long-term environmental exposures at the main terminals of five of the participating airlines and at the NASA-Langley Research Center. Periodic removal and test of the exposed specimens are being performed to determine if the material properties are being degraded by ground-based exposure and to provide correlation with the static strength tests of spoilers removed from flight service.

An installation device was developed which allows multiple specimens to be mounted in individual panels, five of which are fastened to the exposure rack frame with quick-release fasteners that permit removal of one panel without disturbing adjacent panels. Figure 18 shows a typical installation of the exposure rack assembly on the roof of the VASP headquarters building at Congonhas Airport in Sao Paulo, Brazil. A closeup view of one panel is included. Similar installations have been made at airline terminals at Wellington, New Zealand; Frankfurt, Germany; Honolulu, U.S.A.; San Diego, U.S.A.; and at NASA-Langley Research Center. Short beam shear, flexure, and compression specimens are being exposed. At specified intervals, one panel is removed from each rack, packaged to maintain the local moisture content, and shipped to Langley Research Center for testing. Initial specimen exposure began in the fall of 1973 and will continue for at least 5 years.

Tables 6, 7, and 8 give results of tests on shear, flexure, and compression specimens of the three graphite-epoxy material systems following 1 year of environmental exposure at five of the six sites. Comparisons with the test results on unexposed baseline specimens are made in the bar graphs of figures 19, 20, and 21. These three material systems show generally less than 10% change in mechanical properties. Moisture pickup by these materials has been generally less than 1% based on changes in specimen weight. Although the change in material properties is about the same order of magnitude as the change in static strength and stiffness of the spoilers, neither is large enough to be significant by itself. The overall effects of the first year of the outdoor exposure program are summarized in table 9.

Mechanical property tests are conducted generally in keeping with appropriate ASTM standards. The short beam shear specimens are tested at a nominal 4 : 1 span-to-depth ratio; the flexure specimens are tested at a nominal 32 : 1 span-to-depth ratio; and the compression specimens are gripped on fiberglass end tabs and tested in an ITTRI-designed compression fixture (ref. 2). No test results are available from the Sao Paulo, Brazil, installation as that installation has not yet been deployed for 1 year. No attempts have been made to rank the exposure sites for severity based on the first year data.

Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124

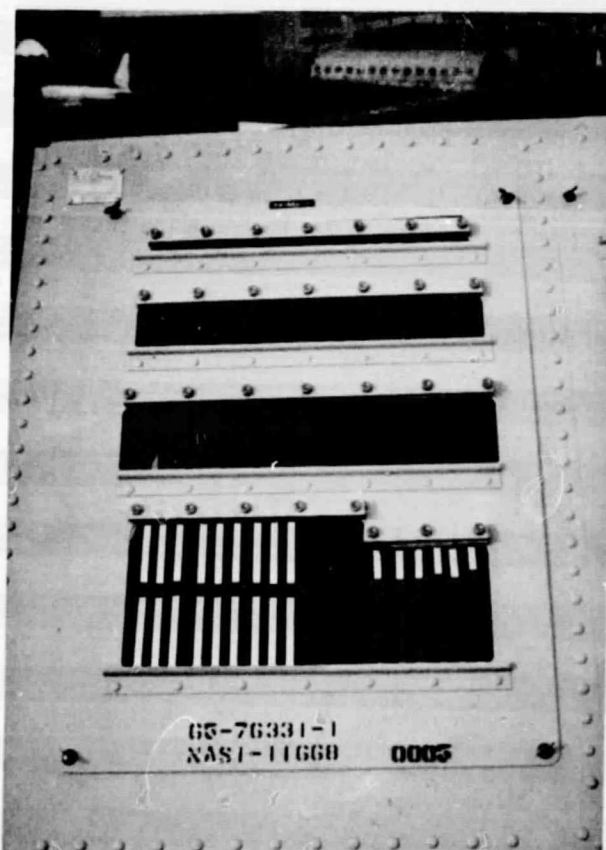
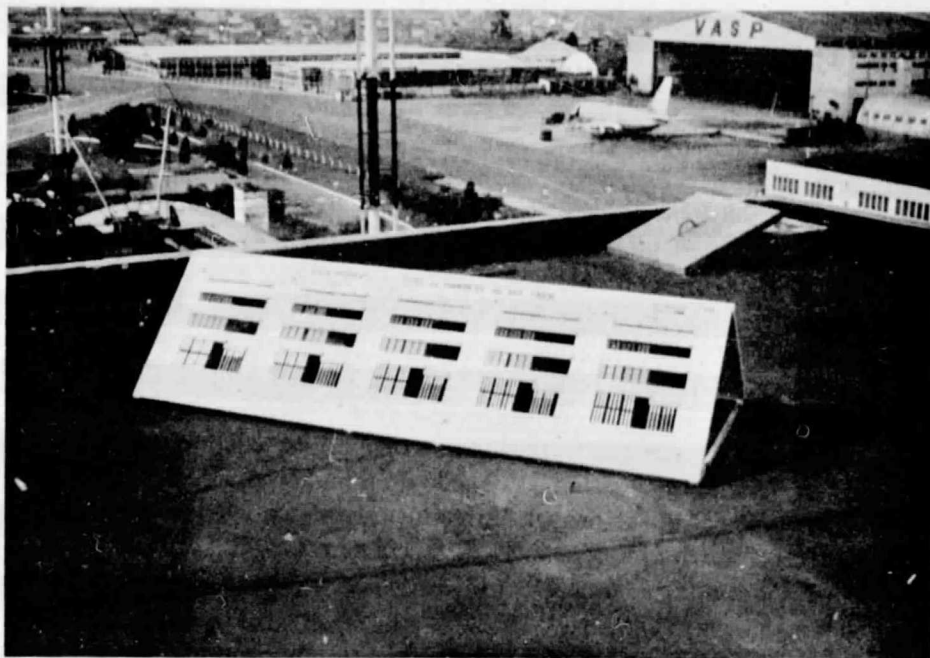


Figure 18.—Exposure Rack Installation—Sao Paulo, Brazil

Table 6.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Short-Beam Interlaminar Shear Tests

| Exposure time, yr | Exposure location | Graphite-epoxy material system | Number of specimens | Av failure stress | | Av wt change | |
|-------------------|------------------------------------------|--------------------------------|---------------------|-------------------|------|--------------|-------|
| | | | | MPa | ksi | grams | % |
| 0 (baseline) | LaRC | T300/5209 | 5 | 77 | 11.2 | — | — |
| 1 | LaRC | T300/5209 | 2 | 78 | 11.3 | +0.0042 | +0.58 |
| 1 | Hawaii | T300/5209 | 3 | 78 | 11.3 | +0.0034 | +0.46 |
| 1 | New Zealand | T300/5209 | 3 | 81 | 11.7 | +0.0039 | +0.50 |
| 1 | Germany | T300/5209 | 3 | 72 | 10.4 | +0.0032 | +0.44 |
| 1 | California | T300/5209 | 3 | 78 | 11.3 | +0.0042 | +0.53 |
| 1 | LaRC ^a (painted specimens) | T300/5209 | 3 | 81 | 11.7 | +0.0029 | +0.34 |
| 0 (baseline) | LaRC | T300/2544 | 4 | 81 | 11.7 | — | — |
| 1 | LaRC | T300/2544 | 3 | 74 | 10.7 | +0.0082 | +1.28 |
| 1 | Hawaii | T300/2544 | 3 | 65 | 9.4 | +0.0067 | +1.07 |
| 1 | New Zealand | T300/2544 | 3 | 73 | 10.6 | +0.0075 | +1.15 |
| 1 | Germany | T300/2544 | 3 | 73 | 10.6 | +0.0066 | +1.09 |
| 1 | California | T300/2544 | 3 | 74 | 10.8 | +0.0071 | +1.14 |
| 1 | LaRC ^a (painted specimens) | T300/2544 | 3 | 80 | 11.6 | +0.0063 | +0.84 |
| 0 (baseline) | LaRC | AS/3501 | 5 | 87 | 12.6 | — | — |
| 1 | LaRC | AS/3501 | 3 | 86 | 12.5 | +0.0050 | +0.80 |
| 1 | Hawaii | AS/3501 | 3 | 89 | 12.9 | +0.0045 | +0.72 |
| 1 | New Zealand | AS/3501 | 3 | 85 | 12.4 | +0.0051 | +0.84 |
| 1 | Germany | AS/3501 | 3 | 78 | 11.3 | +0.0057 | +0.92 |
| 1 | California | AS/3501 | 3 | 84 | 12.2 | +0.0058 | +0.89 |
| 1 | LaRC ^a (painted specimens) | AS/3501 | 3 | 92 | 13.4 | +0.0034 | +0.48 |

^aPainted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

Table 7.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Flexure^a Tests

| Exposure time, yr | Exposure location | Graphite-epoxy material system | Number of specimens | Av failure stress | | Av flex. modulus | | Av wt change | |
|-------------------|------------------------------------------|--------------------------------|---------------------|-------------------|-------|------------------|--------------------------|--------------|-------|
| | | | | MPa | ksi | GPa | psi (x 10 ⁶) | grams | % |
| 0 (baseline) | LaRC | T300/5209 | 5 | 1529 | 221.8 | 103.8 | 15.05 | — | — |
| 1 | LaRC | T300/5209 | 3 | 1429 | 207.3 | 99.0 | 14.36 | +0.0070 | +0.32 |
| 1 | Hawaii | T300/5209 | 3 | 1478 | 214.4 | 108.1 | 15.68 | +0.0052 | +0.23 |
| 1 | New Zealand | T300/5209 | 3 | 1548 | 224.5 | 107.4 | 15.58 | +0.0056 | +0.27 |
| 1 | Germany | T300/5209 | 3 | 1476 | 214.0 | 98.9 | 14.34 | +0.0069 | +0.32 |
| 1 | California | T300/5209 | 3 | 1478 | 214.4 | 107.7 | 15.62 | +0.0091 | +0.41 |
| 1 | LaRC ^b (painted specimens) | T300/5209 | 3 | 1470 | 213.2 | 106.8 | 15.49 | +0.0074 | +0.30 |
| 0 (baseline) | LaRC | T300/2544 | 5 | 1600 | 232.0 | 106.2 | 15.41 | — | — |
| 1 | LaRC | T300/2544 | 3 | 1444 | 209.4 | 104.7 | 15.18 | +0.0092 | +0.50 |
| 1 | Hawaii | T300/2544 | 3 | 1469 | 213.0 | 107.3 | 15.56 | -0.0031 | -0.18 |
| 1 | New Zealand | T300/2544 | 3 | 1580 | 229.1 | 109.4 | 15.86 | +0.0063 | +0.34 |
| 1 | Germany | T300/2544 | 3 | 1597 | 231.6 | 107.6 | 15.60 | +0.0120 | +0.62 |
| 1 | California | T300/2544 | 3 | 1537 | 222.9 | 107.5 | 15.59 | +0.0152 | +0.81 |
| 1 | LaRC ^b (painted specimens) | T300/2544 | 3 | 1603 | 232.5 | 111.8 | 16.21 | +0.0138 | +0.66 |
| 0 (baseline) | LaRC | AS/3501 | 5 | 1449 | 210.1 | 94.7 | 13.73 | — | — |
| 1 | LaRC | AS/3501 | 3 | 1447 | 209.8 | 98.3 | 14.25 | +0.0080 | +0.43 |
| 1 | Hawaii | AS/3501 | 3 | 1398 | 202.7 | 96.7 | 14.03 | +0.0052 | +0.28 |
| 1 | New Zealand | AS/3501 | 3 | 1520 | 220.4 | 100.5 | 14.57 | +0.0070 | +0.41 |
| 1 | Germany | AS/3501 | 3 | 1528 | 221.6 | 96.1 | 13.94 | +0.0102 | +0.53 |
| 1 | California | AS/3501 | 2 | 1518 | 220.2 | 100.1 | 14.52 | +0.0142 | +0.74 |
| 1 | LaRC ^b (painted specimens) | AS/3501 | 3 | 1638 | 237.6 | 99.8 | 14.48 | +0.0087 | +0.37 |

^aFlexure specimens were fabricated from laminates with ply orientations identical to spoiler skin orientation. Specimen length is oriented in the 90° direction of the laminate.

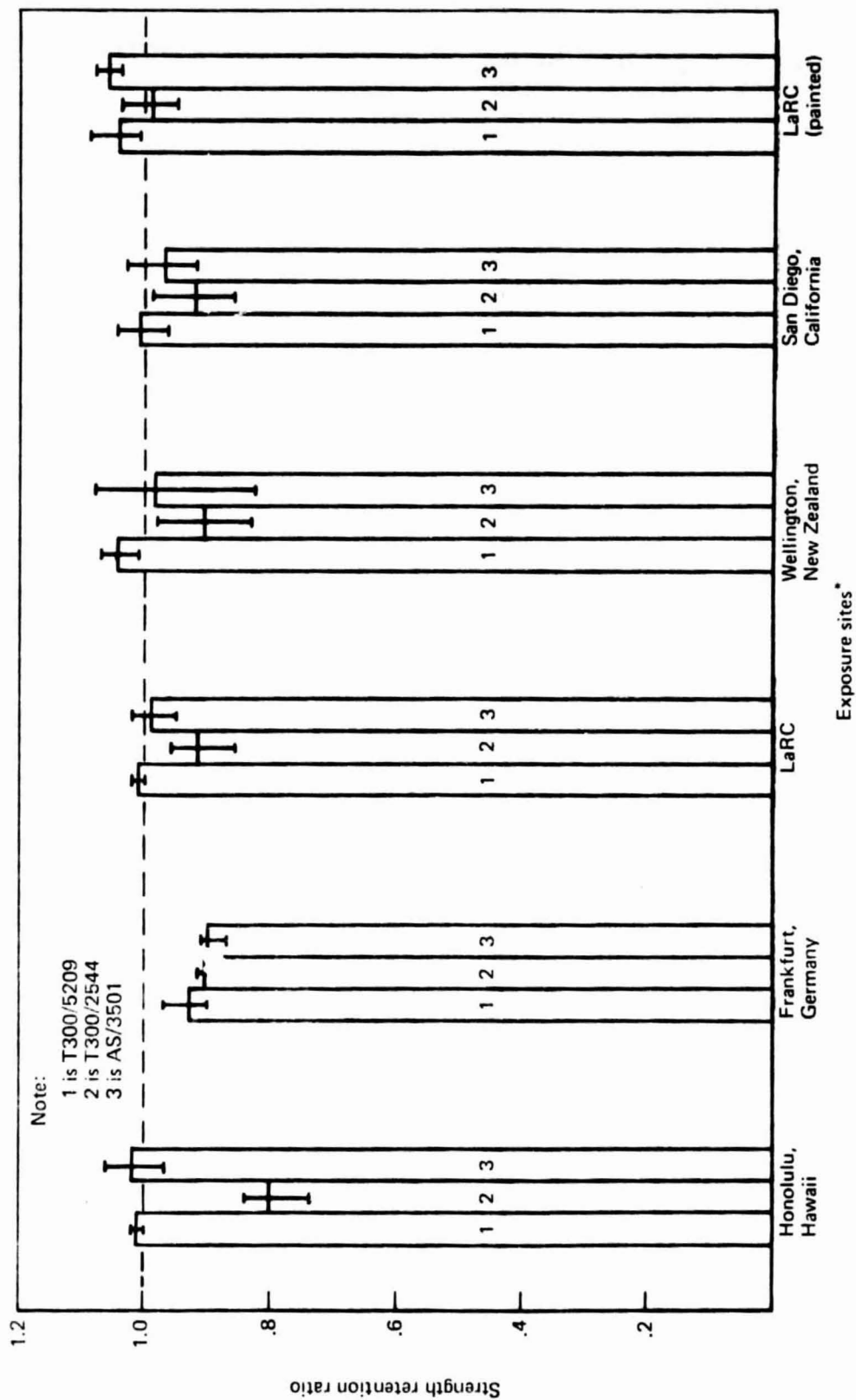
^bPainted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.

Table 8.—Results of Ground-Based Environmental Exposure on Graphite-Epoxy Mechanical Property Test Specimens—Compression^a Tests

| Exposure time, yr | Exposure location | Graphite-epoxy material system | Number of specimens | Av failure stress | | Av wt change | |
|-------------------|------------------------------------------|--------------------------------|---------------------|-------------------|-------|--------------|-------|
| | | | | MPa | ksi | grams | % |
| 0 (baseline) | LaRC | T300/5209 | 3 | 712 | 103.2 | — | — |
| 1 | LaRC | T300/5209 | 3 | 760 | 110.3 | +0.0494 | +0.61 |
| 1 | Hawaii | T300/5209 | 3 | 676 | 98.1 | +0.0556 | +0.70 |
| 1 | New Zealand | T300/5209 | 3 | 647 | 93.8 | +0.0551 | +0.71 |
| 1 | Germany | T300/5209 | 3 | 709 | 102.8 | +0.0389 | +0.49 |
| 1 | California | T300/5209 | 3 | 716 | 103.9 | +0.0588 | +0.74 |
| 1 | LaRC ^b (painted specimens) | T300/5209 | 3 | 654 | 94.9 | +0.0361 | +0.45 |
| 0 (baseline) | LaRC | T300/2544 | 4 | 1029 | 149.2 | — | — |
| 1 | LaRC | T300/2544 | 3 | 985 | 142.9 | +0.0544 | +0.77 |
| 1 | Hawaii | T300/2544 | 3 | 988 | 143.3 | +0.0636 | +0.86 |
| 1 | New Zealand | T300/2544 | 3 | 865 | 125.5 | +0.0723 | +1.02 |
| 1 | Germany | T300/2544 | 3 | 1022 | 148.3 | +0.0497 | +0.70 |
| 1 | California | T300/2544 | 2 | 1031 | 149.6 | +0.0560 | +0.78 |
| 1 | LaRC ^b (painted specimens) | T300/2544 | 3 | 1018 | 147.7 | +0.0521 | +0.74 |
| 0 (baseline) | LaRC | AS/3501 | 5 | 1107 | 160.6 | — | — |
| 1 | LaRC | AS/3501 | 3 | 1045 | 151.6 | +0.0440 | +0.68 |
| 1 | Hawaii | AS/3501 | 3 | 1080 | 156.6 | +0.0461 | +0.69 |
| 1 | New Zealand | AS/3501 | 3 | 1002 | 145.4 | +0.0493 | +0.74 |
| 1 | Germany | AS/3501 | 3 | 1161 | 168.4 | +0.0374 | +0.57 |
| 1 | California | AS/3501 | 3 | 1105 | 160.2 | +0.0531 | +0.81 |
| 1 | LaRC ^b (painted specimens) | AS/3501 | 3 | 1144 | 165.9 | +0.0384 | +0.58 |

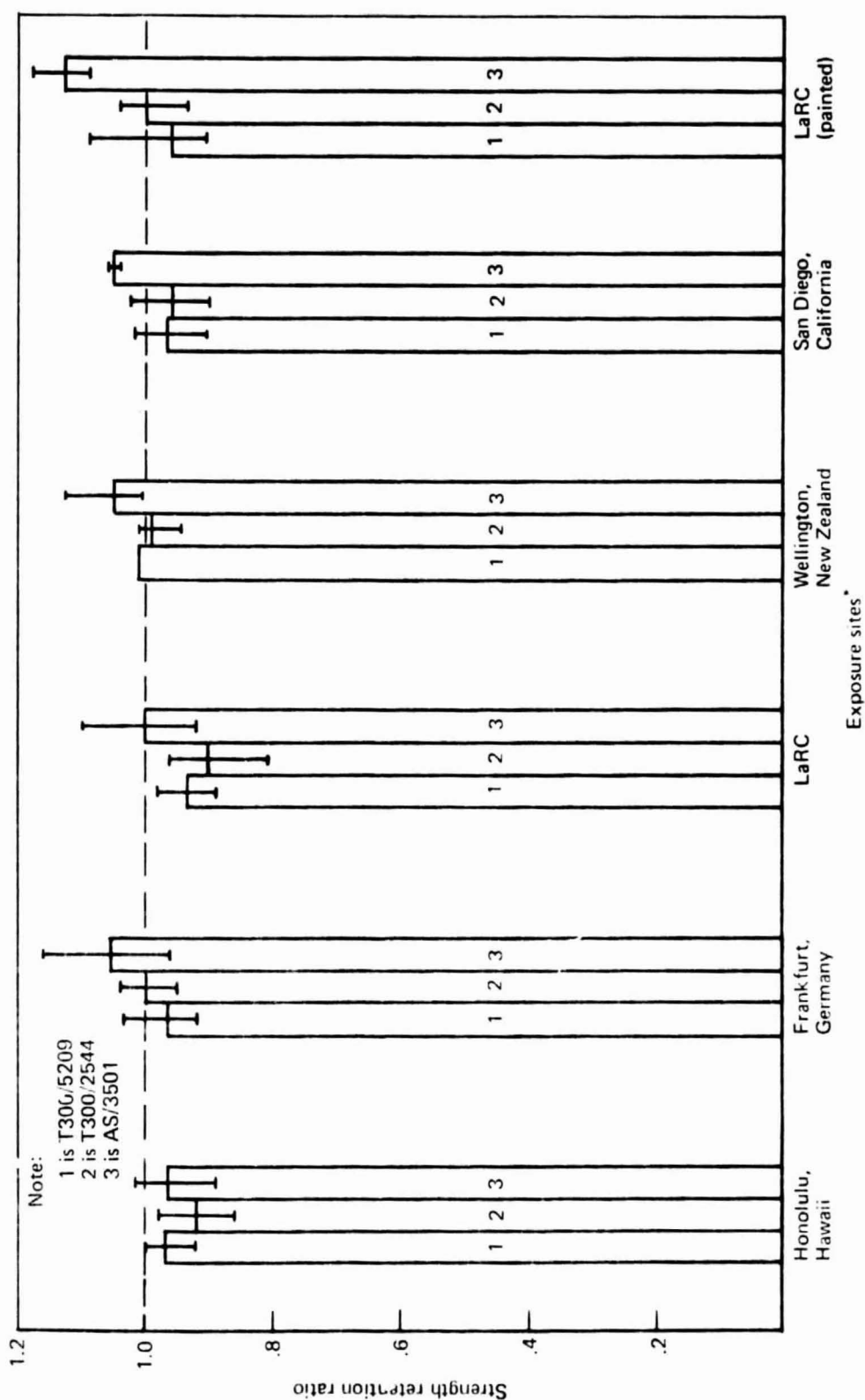
^aCompression specimens were fabricated from laminates with ply orientations identical to spoiler skin ply orientation. Specimen length is oriented in the 90° direction of the skin laminate.

^bPainted specimens were fully coated with a polyurethane-based enamel over a calcium chromate primer prior to exposure at the Langley site.



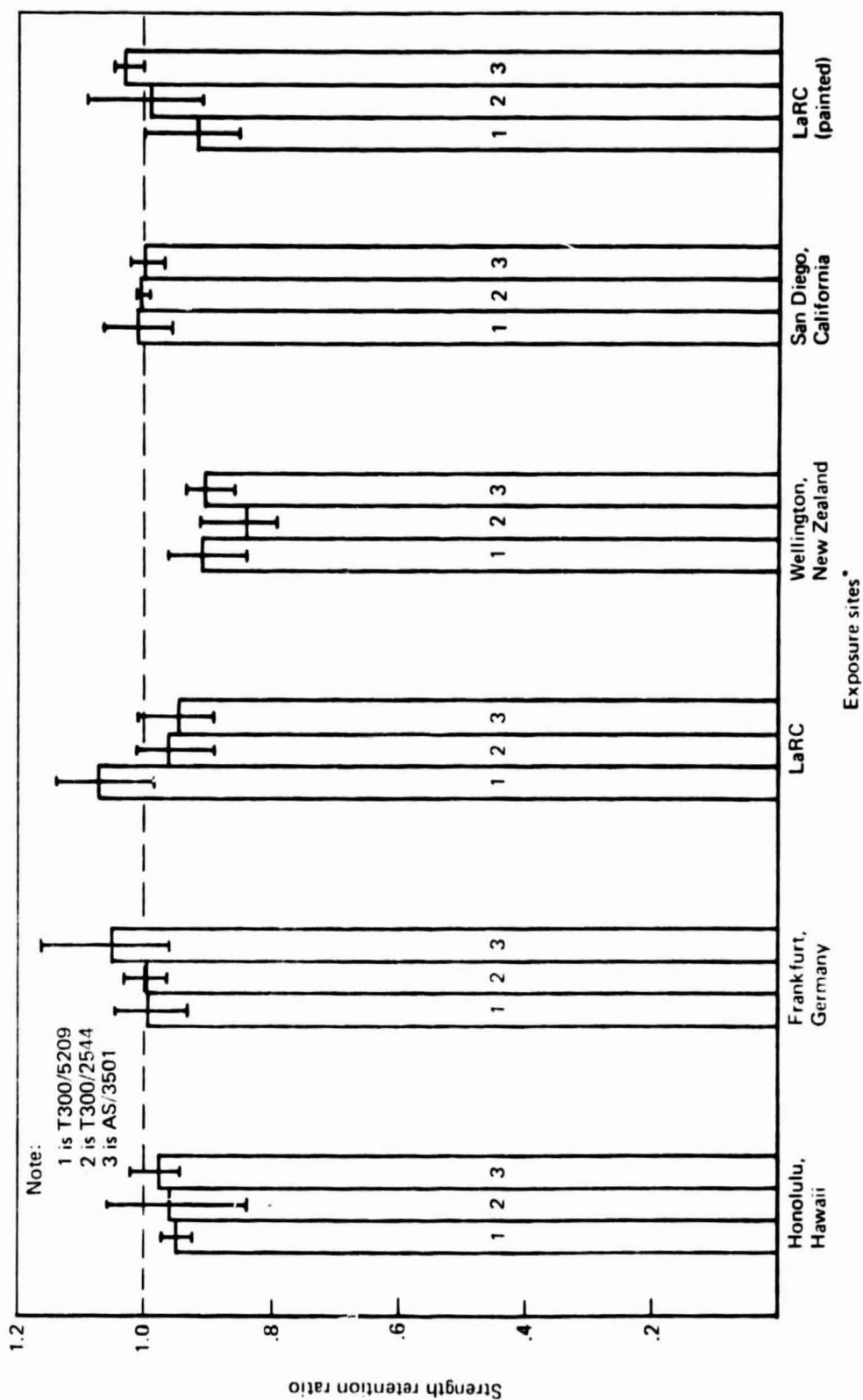
* The Sao Paulo, Brazil, site has not yet completed 1-yr exposure.

Figure 19.—Interlaminar Shear Strengths of Graphite-Epoxy Composites After 1-Year Outdoor Ground Exposure



* The Sao Paulo, Brazil, site has not yet completed 1-yr exposure.

Figure 20.—Flexure Strengths of Graphite-Epoxy Composites After 1-Year Outdoor Ground Exposure



*The Sao Paulo, Brazil, site has not yet completed 1-yr exposure.

Figure 21. - Compression Strengths of Graphite-Epoxy Composites After 1-Year Outdoor Ground Exposure

Table 9.—Overall Effects of 1-Year Outdoor Exposure (Graphite-Epoxy)

| | Overall average change in properties | | | Extremes of change | Overall effect |
|----------------------|--------------------------------------|----------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| | T300/5209 | T300/2544 | AS/3501 | | |
| Flex modulus | 0.4% incr | 1.0% incr | 3.9% incr | 4.7% decr (T300/5209), Germany to 6.1% incr (AS/3501), New Zealand | 1.8% incr |
| Flexure strength | 3.1% decr | 4.7% decr | 2.3% incr | { 6.5% decr, LaRC 1.2% incr, New Zealand 9.7% decr, LaRC 0.2% decr, Germany 3.5% decr, Hawaii 5.5% incr, Germany | 1.8% decr |
| Shear strength | 0% decr | 11.1% decr | 2.7% decr | { 7.1% decr, Germany 4.5% incr, New Zealand 19.7% decr, Hawaii 7.7% decr, California 10.3% decr, Germany 2.4% incr, Hawaii | 4.6% decr |
| Compression strength | 1.4% decr | 4.9% decr | 2.6% decr | { 9.1% decr, New Zealand 6.9% incr, LaRC 15.9% decr, New Zealand 0.3% incr, California 9.5% decr, New Zealand 4.9% incr, Germany | 3.0% decr |
| Weight gain | 0.486% gain | 0.801% gain | 0.670% gain | | 0.652% gain |

REFERENCES

1. Stoecklin, R. L.: *A Study of the Effects of Long-Term Ground and Flight Environment Exposure on the Behavior of Graphite-Epoxy Spoilers*. D6-60170-1 through -8. Quarterly Progress Reports (8). Boeing Commercial Airplane Company, Oct. 1972 through July 1974.
2. Hofer, K. E.; et al.: *Development of Engineering Data on the Mechanical and Physical Properties of Advanced Composites Materials*. AFML-TR-72-205. Part I. ITT Research Institute, Sept. 1972. pp. 148-159.